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National
Voluntary
Laboratory
Accreditation
Program

Efficiency of Electric Motors

Lawrence S. Galowin
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Wiley A. Hall

NIST HANDBOOK 150-10

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Technology Administration
National Institute of Standards
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[2] Some elements at Boulder, CO 80303.

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National Voluntary Laboratory Accreditation Program

Efficiency of Electric Motors

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FOREWORD

JOINT PROGRAM

of the

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)
NATIONAL VOLUNTARY LABORATORY ACCREDITATION PROGRAM (NVLAP)

and

STANDARDS COUNCIL OF CANADA (SCC)
PROGRAM FOR ACCREDITATION OF LABORATORIES - CANADA (PALCAN)

The *Efficiency of Electric Motors* handbook provides the technical requirements of a joint program for accreditation of testing laboratories by the National Voluntary Laboratory Accreditation Program (NVLAP) and the Program for Accreditation of Laboratories - Canada (PALCAN).

The basis for the joint laboratory accreditation program is the Mutual Recognition Agreement (MRA) between the National Institute of Standards and Technology (NIST) and the Standards Council of Canada (SCC). The MRA provides for mutual recognition of the testing laboratory accreditation systems administered by both organizations. The Efficiency of Electric Motors accreditation program supports mandated energy conservation requirements by providing assurance of test laboratory competency. The MRA requires that all laboratories accredited by NVLAP and SCC participate satisfactorily in the proficiency testing program conducted by NVLAP.

At the time of publication of the handbook, the U.S. Department of Energy (DoE) was preparing to publish regulations following the rule-making procedures. Other requirements and conditions may be announced for manufacturer self-declarations, based upon accredited laboratory data, for conformance to the requirements of the Energy Policy Act of 1992 (EPACT). For purposes related to special DoE requirements for laboratory accreditation, users of this handbook should request supplementary information from NVLAP.

In the United States, DoE will require NVLAP accreditation of laboratories for test data reports that provide the basis for manufacturer self-declarations that attest to electric motor(s) performance for conformance to regulations from the Energy Policy Act. DoE will accept SCC/PALCAN accreditation of laboratories for test data reports for the same purpose. Manufacturers' declarations for conformance to regulations for compliance must be based upon test results from either NVLAP- or SCC/PALCAN-accredited laboratories.

Natural Resources Canada has published regulations under the Energy Efficiency Act, 1992, which requires certification of electric motors by "markings" that will establish compliance as specified by Canadian authority, compatible with specific provincial legislative requirements. The Canadian energy performance verification program requires a certification body, accredited by SCC, that is recognized capable to administer a program that verifies fulfillment of the energy efficiency standards. A certification body may select laboratories to provide test data that are accredited by NVLAP or SCC. Other laboratories may also be selected, for which it is recommended that for testing comparability purposes in recognition/acceptance of data, conformance to ISO/IEC Guide 25 criteria for competency and quality can be confirmed, and that those laboratories be participants in the proficiency testing program.

PREFACE

NIST Handbook 150-10 presents the technical requirements of the National Voluntary Laboratory Accreditation Program (NVLAP) for the Efficiency of Electric Motors (EEM) field of accreditation. The same document is published for use by the Standards Council of Canada (SCC); selected differences may be specified for implementation in both countries.

This handbook is intended for information and use by staff of accredited laboratories, those laboratories seeking accreditation, other laboratory accreditation systems, users of laboratory services, and others needing information on the requirements for accreditation under the EEM program. The NVLAP/SCC Mutual Recognition Agreement calls for all participants in the joint electric motors program to participate in the NVLAP proficiency testing program. Interested organizations requiring information concerning participation in the proficiency testing (PT) program portion of the program can request an application for PT from NVLAP.

This publication supplements NIST Handbook 150, *NVLAP Procedures and General Requirements*, which contains Part 285 of Title 15 of the U.S. Code of Federal Regulations (CFR) plus all general NVLAP procedures, criteria, and policies. The criteria in NIST Handbook 150 encompass the requirements of ISO/IEC Guide 25 and the relevant requirements of ISO 9002 (ANSI/ASQC Q92-1987). Handbook 150-10 contains information that is specific to the EEM program and does not duplicate information contained in the Procedures and General Requirements. The numbering of the sections of this handbook is patterned after Handbook 150; for example, Section 285.3 of Handbook 150 presents the description and goal of NVLAP, whereas Section 285.3 of Handbook 150-10 presents only the description of the EEM program. Where there is no material specific to the field of accreditation, the section number is omitted.

Any questions or comments on this handbook should be submitted to:

National Institute of Standards and Technology
National Voluntary Laboratory Accreditation Program
Building 411, Room A162
Gaithersburg, MD 20899
Phone: (301) 975-4016
Fax: (301) 926-2884
E-mail: nvlap@enh.nist.gov.

In Canada, contact:

Standards Council of Canada
1200-45 O'Connor
Ottawa, Ontario K1P 6N7
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Fax: (613) 995-4564.

TABLE OF CONTENTS

FOREWORD iii

PREFACE iv

ACKNOWLEDGMENTS vi

SUMMARY vii

Sec. 285.1 Purpose 1

Sec. 285.2 Organization of procedures 1

Sec. 285.3 Description of Efficiency of Electric Motors program 1

Sec. 285.4 References 2

Sec. 285.5 Definitions 3

Sec. 285.6 NVLAP documentation 3

Sec. 285.22 Assessing and evaluating a laboratory 4

Sec. 285.23 Granting and renewing accreditation 6

Sec. 285.33 Criteria for accreditation 6
- (c) Quality system, audit and review 6
- (d) Personnel 7
- (e) Accommodation and environment 8
- (f) Equipment and reference materials 8
- (g) Measurement traceability and calibration 9
- (h) Calibration and test methods 9
- (j) Records 10
- (k) Certificates and reports 10
- (m) Outside support services and supplies 11

APPENDICES
- SAMPLE ACCREDITATION DOCUMENTS A-1
- GENERAL OPERATIONS CHECKLIST B-1
- SPECIFIC OPERATIONS CHECKLIST C-1
- TEST METHOD SELECTION LIST D-1
- ON-SITE ASSESSMENT - TEST METHOD REVIEW E-1
- ON-SITE ASSESSMENT REPORT COVER SHEET F-1
- REPORT ILLUSTRATION G-1

ACKNOWLEDGMENTS

The technical requirements for the Efficiency of Electric Motors (EEM) Program described in this handbook were developed in cooperation with the Motors and Generators Section of the National Electrical Manufacturers Association (NEMA). A NEMA task group was organized to work with NVLAP staff. The handbook authors acknowledge the contributions of the NEMA task group members, whose activities were coordinated by Dr. Roger Daugherty, of Reliance Electric Co., in suggesting and reviewing the technical requirements proposed for the program. The authors also wish to express their appreciation to the NEMA staff for their efforts in supporting the task group.

The authors thank their NIST colleagues for contributions to the program development: Albert Tholen for guidance and direction; Lawrence Knab and Raymond Turgel for review of the handbook; and Vanda White for her steadfastness in editing, revising, and arranging publication of the handbook. Channing Monti and Maria Lancaster also provided editorial assistance. Thanks are also extended to Anthony Balducci, DOE, for his review and comments on the handbook.

SUMMARY

Any laboratory (including commercial, manufacturer, university, or federal, state, or local government laboratory) that performs the test method that comprises the EEM Program may apply for NVLAP accreditation. Accreditation will be granted to a laboratory that satisfactorily fulfills the conditions for accreditation defined in the NVLAP Procedures: Title 15, Part 285 of the Code of Federal Regulations (see NIST Handbook 150). These conditions include satisfactory performance in selected proficiency testing as required, and fulfilling the on-site assessment requirements, including resolution of identified deficiencies. The names of NVLAP-accredited laboratories are published in the NVLAP annual directory and other media to which information is regularly provided.

Test method covered: The scope of the EEM Program covers test procedures specified in IEEE Standard 112 Method B, (CSA Standard C390 Method 1) for electric motor efficiency. This scope is consistent with the requirements of the Energy Policy Act of 1992, U.S. Public Law 102-486 (EPACT) and the Energy Efficiency Act Canada, June 1992.

Period of accreditation: One year, renewable annually.

On-site assessment: Visit by a technical expert to determine compliance with the NVLAP criteria before initial accreditation and every two years thereafter. Additional monitoring visits as required.

Assessors: Technical experts with experience in testing the efficiency of electric motors.

Proficiency testing: The NIST/SCC MRA calls for all participants in the joint EEM program to participate in the NVLAP proficiency testing program. In this program, each laboratory is required to test and analyze proficiency testing sample material(s) for IEEE Standard 112 Method B (CSA C390 Method 1).

Proficiency testing is conducted annually. Advance notice and instructions are given before testing is scheduled. The completed test data report is sent to NVLAP or, as directed, to the proficiency testing contractor. A summary of results is sent to the participants.

Laboratories that are not enrolled in NVLAP, but are interested in participating in the proficiency testing program, may request a proficiency testing application from NVLAP.

Granting accreditation: Based upon satisfactory on-site assessment and resolution of deficiencies, proficiency testing, and technical evaluation of applicable laboratory information.

Fees: Payments are required as listed on the fee schedule, including the administrative/technical support fee, on-site assessment fee, proficiency testing fee, and test method fee.

Sec. 285.1 Purpose

The purpose of this handbook is to set out procedures and technical requirements for accreditation by NVLAP of laboratories which perform test procedures covered by the Efficiency of Electric Motors (EEM) program. It complements and supplements the NVLAP programmatic procedures and general requirements found in NIST Handbook 150. The interpretive comments and additional requirements contained in this handbook make the general NVLAP criteria specifically applicable to the EEM program.

Sec. 285.2 Organization of procedures

(a) The procedures for accreditation described in this handbook are organized to cross-reference with NIST Handbook 150, *NVLAP Procedures and General Requirements*.

(b) In addition, the handbook contains seven appendices:

(1) Appendix A provides examples of a Certificate of Accreditation and a Scope of Accreditation for the EEM program;

(2) Appendix B provides the General Operations Checklist, which NVLAP assessors use during an on-site technical assessment to evaluate a laboratory's ability to conduct testing in general;

(3) Appendix C provides the Specific Operations Checklist, which NVLAP assessors use during an on-site technical assessment of a laboratory that tests the efficiency of electric motors;

(4) Appendix D lists the standard test method and its accompanying NVLAP Code for the EEM Program as given on the NVLAP Test Method Selection List;

(5) Appendix E provides the sheets that the assessor completes in conducting a test method review;

(6) Appendix F shows an on-site assessment report cover sheet that is signed by the assessor and laboratory representative at the conclusion of the exit briefing; and

(7) Appendix G gives an example of the technical information that is included in the report written by the laboratory.

Sec. 285.3 Description of Efficiency of Electric Motors program

(a) The purpose of the EEM program is to accredit testing laboratories to assure that standard test procedures for efficiency are followed in testing electric motors. Specifically, the EEM program addresses testing the efficiency of electric motors according to the scope and procedures given in Method B of Institute of Electrical and Electronics Engineers (IEEE) Standard 112, *Test Procedure for Polyphase Induction Motors and Generators*, and Method 1 of Canadian Standards Association (CSA) Standard C390 *Energy Efficient Test Methods for Three-Phase Induction Motors*. IEEE 112 indicates (Section 6.2.1) that polyphase motors larger than 250 horsepower may be tested by Method B. Consequently, laboratories for testing motors greater than 250 horsepower can request accreditation in this program.

(b) CSA C390 is the Canadian counterpart to IEEE 112. CSA C390 is used in Canadian laboratory accreditation and related programs for electric motor efficiency, particularly those prescribed by Canadian national and provincial regulations. Method 1 of CSA C390 is essentially the same as Method B of IEEE 112. The test procedures in both are equivalent so that the raw data obtained in conducting tests according to either standard are identical. A difference between the two is that the CSA standard implies the order in which all of the subtest procedures of the method are to be performed, whereas the IEEE standard is not as specific. Another difference between the two is the method by which the specified temperature, used for the adjustment of the stator resistance and motor slip, is determined when calculating the motor efficiency. Generally, this temperature determination has little effect on the calculated value for motor efficiency except under infrequent circumstances (see Sec. 285.33 (k)(2)).

Within the NVLAP EEM Program, accreditation to the IEEE Standard and CSA Standard is not granted separately. For accreditation purposes, the two standards are considered equivalent because the subtest procedures producing the data on which efficiency is calculated are, for all intents and purposes, the same. Thus, a laboratory granted accreditation to one standard also receives

accreditation to the other. However, any laboratory seeking CSA accreditation or all laboratories submitting efficiency values to regulatory agencies must use the calculation procedure given in Method 1 of CSA C390 to assure uniform reporting of motor efficiency. A laboratory specifically seeking accreditation to CSA C390 Method 1 must demonstrate during the course of its assessment that it conducts the subtest procedures according to the order stipulated in the standard.

(c) Public Law 102-486, *Energy Policy Act of 1992*, (October 24, 1992), referred to as EPACT, requires that the Department of Energy (DOE) specify energy efficiency standards for certain types of electric motors rated from 1 to 200 horsepower. The law stipulates that the testing of motor efficiency is to be conducted according to the procedures in Method B of IEEE Standard 112, as in effect on the date of the enactment of EPACT. DOE has some flexibility under EPACT to amend the procedures in IEEE 112 in promulgating the rule on motor efficiency. The EEM accreditation program was developed at the request of the National Electrical Manufacturer's Association (NEMA) to assist the electric motor industry in complying with the EPACT provisions for electric motors. NVLAP coordinated the development of the EEM program with NEMA and DOE. Some of the EEM program requirements, particularly those associated with the accuracy of instrumentation, are somewhat more stringent than those given in IEEE 112 (CSA C390). DOE is expected to enact these requirements in promulgating the motor efficiency rule.

The horsepower range for which motors that can be tested within the scope of IEEE 112 Method B (CSA C390 Method 1) is greater than the 1 to 200 horsepower provision of EPACT. Some laboratories seeking NVLAP accreditation consistent with the EPACT provisions may have the capability to test motors rated above 200 horsepower. The scope of the EEM program consequently covers the range of motors within the limits of IEEE 112 Method B (CSA C390 Method 1). Testing of the safety performance of electric motors is beyond the scope of the accreditation program.

Sec. 285.4 References

(a) The following documents are referenced or cited in this handbook:

(1) CSA standard C390, *Energy Efficient Test Methods for Three-Phase Induction Motors*;

(2) IEEE standards:

(i) IEEE 4, *IEEE Standard Techniques for High Voltage Testing*;

(ii) IEEE 43, *IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery*;

(iii) IEEE 112, *Test Procedure for Polyphase Induction Motors and Generators*;

(iv) IEEE 118, *Test Code for Resistance Measurements*; and

(v) IEEE 120, *Master Test Guide for Electrical Measurements in Power Circuits*;

(3) ISO/IEC Guide 25, *General Requirements for the Competence of Calibration and Testing Laboratories;*

(4) ISO 9002, *Quality Systems-Model for Quality Assurance in Production and Installation;*

(5) NCSL (National Conference of Standards Laboratories) Recommended Practice #7, *Laboratory Design*; July 25, 1993; and

(6) NIST Handbook 150, *NVLAP Procedures and General Requirements*.

(b) Sources for the above-referenced documents follow:

(1) CSA standard C390 may be ordered from:

Canadian Standards Association
178 Rexdale Boulevard
Rexdale, Ontario M9W 1R3
Canada

Phone: (416) 747-4044
Order Fax: (416) 747-2475;

(2) IEEE standards may be ordered from:

Institute of Electrical and Electronics Engineers (IEEE)
Service Center
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331

Phone: (908) 562-3800
Order Fax: (908) 562-1571;

(3) ISO/IEC Guide 25 and ISO 9002 may be ordered from:

American National Standards Institute
11 West 42 Street, 13th Floor
New York, NY 10036

Order Phone: (212) 642-4900
Order Fax: (212) 302-1286;

(4) NCSL Recommended Practice #7 may be ordered from:

NCSL
1800 30th Street, Suite 305B
Boulder, CO 80301

Phone: (303) 440-3339
Fax: (303) 440-3384;

(5) NIST Handbook 150 may be obtained from:

National Institute of Standards and Technology (NIST)
National Voluntary Laboratory Accreditation Program (NVLAP)
Building 411, Room A162
Gaithersburg, MD 20899

Phone: (301) 975-4016
Fax: (301) 926-2884.

Sec. 285.5 Definitions

Efficiency: The ratio of an electric motor's useful power output to its total power input expressed in percentage.

Sec. 285.6 NVLAP documentation

(a) Test Method Selection List

The Test Method Selection List, provided to the laboratory seeking accreditation as part of the NVLAP application package, lists the methods that comprise the program. Appendix D shows the Test Method Selection List for the EEM program, which contains only the IEEE 112 Method B (CSA C390 Method 1) procedure. Other test methods may be added to the EEM program upon request, following NVLAP procedures for adding to or modifying an established LAP (see Handbook 150, Sec. 285.18).

Note in Appendix D that the laboratory seeking accreditation is requested on the Test Method Selection List to indicate the horsepower range for which it is seeking accreditation.

(b) Checklists

Checklists contain definitive statements or questions about all aspects of the NVLAP criteria for accreditation. NVLAP programs incorporate two types of checklists:

(1) The NVLAP General Operations Checklist addresses factors applicable to evaluating a laboratory's ability to conduct testing in accordance with the procedures and general requirements for accreditation. The factors include, but are not limited to, the laboratory's organization, management, and quality system in addition to its testing competency.

The General Operations Checklist, presented in Appendix B, is numbered to correspond to the requirements in NIST Handbook 150. The comment sheets are used by the assessor to explain findings and deficiencies noted on the checklist, as well as to make comments on aspects of the laboratory's performance other than deficiencies.

(2) The Specific Operations Checklist contains statements or questions that are specific to the test procedures in the EEM program and focus on the testing requirements for the methods with emphasis on performing the tests, testing accuracy, instrumentation, calibration, personnel competency, and test reporting.

The Specific Operations Checklist is presented in Appendix C, along with comment sheets similar to those used with the General Operations Checklist.

Sec. 285.22 Assessing and evaluating a laboratory

(a) On-Site Assessment

(1) The NVLAP assessor may request manuals and/or documented procedures in advance of the on-site assessment to reduce time at the laboratory. Documentation supplied in advance will be returned. The laboratory should be prepared for conducting test demonstrations, have equipment in good working order, and be ready for examination according to the requirements identified in this handbook, NIST Handbook 150, the laboratory's quality manual, and its written test procedures. The assessor will need time and work space to complete assessment documentation during the time at the laboratory.

(2) Along with the Specific Operations Checklist, the assessor uses the instructions and comment sheets shown in Appendix E in reviewing the laboratory's ability to perform the test methods. In a program containing numerous methods, the test method review ranges from observing tests to having laboratory staff describe the test procedures. The assessor notes on the On-Site Assessment - Test Method Review Summary (p. E-4) the depth into which each part of the test method was reviewed. For the EEM program, the test method review is in depth, as only one procedure, IEEE 112 Method B (CSA C390 Method 1), comprises the program.

(3) An assessor performs the following activities during a typical on-site assessment:

(i) Conducts an entry briefing with the laboratory manager to explain the purpose of the on-site visit and to discuss the schedule for the day(s). At the discretion of the laboratory manager, other staff may attend the briefing.

(ii) Reviews laboratory quality manual and its implementation, and records, including the following:

- sample identification and tracking procedures and copies of completed test reports;

- records of periodic internal audits and use of quality control procedures and participation in interlaboratory comparisons or other similar programs; and

- personnel records, including résumés and job descriptions of key personnel and competency evaluations for all staff members who routinely perform the test method for which accreditation is sought.

At least one laboratory staff member must be available to answer questions; however, the assessor may wish to review the documents alone. The assessor usually does not ask to take any laboratory documents with him and documents previously supplied will be returned.

(iii) Physically examines equipment and facilities and observes the demonstration of selected procedures by appropriate personnel assigned to conduct the tests, and interviews those personnel. The demonstrations must include sample test material(s), preparation of devices, establishment of test conditions and the setup/use of major equipment. The assessor may provide the proficiency test sample and request a specific demonstration.

(iv) Completes an On-Site Assessment Report, which contains the minimum requirements prescribed in NIST Handbook 150, Sec. 285.22(b)(2), as well as copies of the completed checklists. At the exit briefing, a discussion of the assessment is carried out. The first page of the report (Appendix F) is signed by the assessor and the laboratory's Authorized Representative to acknowledge the discussion but does not necessarily indicate agreement; challenge(s) may be made through NVLAP. All observations made by the NVLAP assessor are held in the strictest confidence.

(b) Proficiency Testing

(1) NIST Handbook 150 defines (Sec. 285.5) and describes (Sec.285.22 (4)) how proficiency testing is included in the accreditation process. Proficiency testing is required for the EEM program using the IEEE 112 Method B (CSA C390 Method 1) test procedure and, in general,

will be conducted annually. Laboratories renewing accreditation must have satisfactorily participated in all required proficiency testing during their previous accreditation period. Failure to participate is considered a deficiency, and may result in suspension of accreditation.

(2) Proficiency testing in the EEM program will be conducted over the horsepower range of 1-200 horsepower that is covered by EPACT. For laboratories that perform tests outside that range, special arrangements will be made to provide an alternative evaluation. NVLAP may arrange and annually schedule, in conjunction with laboratory-provided information, an assessor to observe one or more electric motor tests conducted by the laboratory. An additional fee payment, in addition to the fee schedule for proficiency testing, may be necessary. A report, jointly prepared by the assessor and the laboratory staff, will be submitted to NVLAP. Deficiency resolution(s), if necessary, will be required following Sec. 285.22(b)(3) of the NVLAP Procedures.

(3) NVLAP conducts the proficiency testing for the EEM program through a proficiency testing contractor.

(4) Annually, each laboratory is sent, (or is instructed to obtain), selected test samples, data sheets, and instructions for test specimen handling, preparation, conditioning, mounting, and testing. Proficiency testing may consist of several parts in order that the operation of a laboratory might be evaluated. Also, portions of the standard test procedure may be "emphasized," e.g., measurement and instrumentation, hardware, and data analysis. Generally, it is required that the specific proficiency test procedure be conducted in accordance with the applicable standard test method. At times special conditions are specified to assure uniformity in procedures and test conditions among participants. Those may include the number of replicate measurements, special operating conditions, and other test parameters. ***The work must not be contracted out to another laboratory.*** Completed test results and data sheets must be returned to NVLAP, or the designated address, by the date specified on the data sheets. Failure to return the data sheets by the deadline may result in penalties which may include suspension of accreditation.

(5) On occasion, the on-site assessor hand carries proficiency test samples to the laboratory. These proficiency test samples, like all others received by the laboratory, are to be listed or entered into the normal tracking and identification system for control and data recording. In these cases, the samples may be returned to the on-site assessor rather than stored at the laboratory. Additionally, in some cases, the laboratory may be instructed to send the proficiency test samples back to the proficiency testing contractor, or to a destination specified by NVLAP or the proficiency testing contractor.

(6) After completion of a given proficiency test round, samples that are not returned to the on-site assessor or proficiency testing contractor become the property of the laboratory for use at its discretion. Experience has shown that these proficiency test samples are often useful to the laboratory as training artifacts, or as calibration-check samples. ***However, in no case shall these proficiency test samples be considered as calibration standards or standard reference materials and be used as substitutes for primary calibration standards that are traceable to national (i.e., NIST) or international standards laboratories.***

(7) Proficiency test data are analyzed using statistical procedures to determine distributions and parameters such as averages, standard deviations, and outliers. The results of the proficiency testing are reported to the participants in appropriate documents and reports. The identity and performance of individual laboratories remain confidential. Test data from proficiency testing must be used in monitoring the laboratory's own performance.

The results of proficiency testing are made available to on-site assessors for use during laboratory assessment visits. If problems are indicated by proficiency testing, they are discussed with appropriate laboratory personnel responsible for developing and implementing plans for resolving the problems. After notification of unsatisfactory performance, the laboratory must take corrective action to resolve the deficiency in a timely manner, similar to the process for on-site assessment deficiency resolution. Failures may result in revocation or suspension of accreditation.

Sec.285.23 Granting and renewing accreditation

Laboratories granted NVLAP accreditation are provided with two documents: a Certificate of Accreditation and a Scope of Accreditation. Samples of these accreditation documents for the EEM program are shown in Appendix A. Note that the certificate states that the criteria encompass the requirements of ISO/IEC Guide 25 and the relevant requirements of ISO 9002 (ANSI/ASQC Q92-1987).

For the EEM program, the scope also lists the horsepower range for which accreditation is granted.

Sec. 285.33 Criteria for accreditation

(c) Quality system, audit and review

(1) Under its quality system, the laboratory shall implement policies and operational procedures covering all of the technical requirements in this handbook. Periodic reviews of the quality system shall reflect adherence to NVLAP requirements and the laboratory's quality objectives. These reviews should reflect positive aspects of the quality system as well as deficiencies.

Examples of operational procedures that must be included in the quality manual are:

(i) procedures for receipt, identification, and tracking of motor test samples;

(ii) procedures by which the laboratory describes the motor test samples and the criteria for their acceptance or rejection;

(iii) the range of motors that the laboratory can test according to IEEE 112 Method B (CSA C390 Method 1);

[NOTE: The type and size of motor test specimens which fall within the scope of the IEEE 112 Method B (CSA C390 Method 1) test procedure is broad. In some cases, a laboratory's test equipment may be limited such that the laboratory cannot measure the efficiency of the complete range of specimens covered by the standard.]

(iv) procedures for interlaboratory comparison and the laboratory's participation in proficiency testing, a summary of the results, and a description of any corrective actions taken because of the results; and

(v) the personnel training and competency evaluations which demonstrate that the test procedures are being followed correctly.

(2) NIST Handbook 150, Sec. 285.33(c)(2) lists quality system requirements that must be included in the quality manual. In addition, for the EEM program, the quality manual must contain or make reference to detailed descriptions of the procedures, practices, and equipment that the laboratory uses in conducting efficiency measurements of electric motors according to IEEE 112 Method B (CSA C390 Method 1).

[NOTE: The standardized efficiency test procedure has been developed to be generally applicable to a variety of electric motors that differ by factors such as size, shape, horsepower, and speed. As a consequence, a laboratory needs to incorporate specific details into the design, construction, and operation of the motor test equipment that it uses to conduct efficiency tests of motors. The detailed descriptions of the test equipment and instrumentation must include the operation and calibration procedures. The uncertainty of the measurement process must be discussed.]

(3) During the on-site assessment, the NVLAP assessor reviews the laboratory's own detailed procedures to perform efficiency tests of electric motors according to the IEEE 112 Method B (CSA C390 Method 1) procedure, the range of motor specimens it can test, and the descriptions of the maintenance and calibration of its specific equipment. Such descriptions may be prepared in a form convenient to the particular needs of the laboratory, but all the elements required by NVLAP procedures must be covered. The documentation must be readily available to the staff.

(4) The quality manual shall contain a description of the procedures that the laboratory uses to evaluate the uncertainty of its measurements using within-laboratory or replicate testing.

(5) The most recent publication of the IEEE 112 and CSA C390 standards shall be available as references and, except as discussed in the following paragraph, are to be followed in conducting the given test procedures. Additionally, the laboratory shall have ready access to the most recent publications of IEEE standards 4, 43, 118, and 120. (see Sec. 285.4 *References*). These documents provide direction in properly conducting the procedures given in IEEE 112 Method B (CSA C390 Method 1).

As mentioned in the program description (Sec. 285.3), EPACT requires that motor efficiency be tested according to Method B of IEEE Standard 112 as in effect at the date of enactment of the public law. If this test standard is revised, DOE can only include the revised method in its regulations for motor efficiency by a rule modification established through the regulatory process. Until that occurs, DOE would continue to require that motor efficiency data be submitted from laboratories accredited to the IEEE 112 version in effect at the time of the enactment of EPACT. If this situation arises, in accordance with its procedures, NVLAP will offer accreditation to the revised version of the IEEE standard to any laboratory that requests it. For laboratories that are accredited because of EPACT requirements, NVLAP will continue to accredit them to the version of IEEE 112 that is required by the EPACT rule, provided that it is technically sound to do so. Consequently, in such a case, the laboratory must have available the applicable version of the IEEE 112 Standard.

(d) Personnel

(1) The laboratory shall maintain records on each staff member, including a résumé of qualifications; laboratory testing procedures to which the person is assigned; and the results of periodic testing performance reviews, which may include intra-operator tests and interlaboratory tests.

[NOTE: For the purpose of on-site assessments, a separate personnel folder of information specific to applicable NVLAP requirements may be provided instead of the complete folder that may contain confidential information not needed for the accreditation assessment.]

(2) The laboratory shall have a description of its training program for ensuring that staff are able to perform tests properly.

(3) The laboratory shall ensure that each new staff member is trained for the testing duties assigned and that staff members are retrained when they are assigned new responsibilities or when test methods are updated.

(4) The laboratory shall evaluate the competency of each staff member for each test method the staff member is authorized to conduct.

(i) An evaluation and observation of performance shall be conducted annually by the immediate supervisor, or a designee appointed by the laboratory director, and must be adequately documented.

(ii) A record of the annual evaluation of each staff member must be dated and signed by the supervisor and the employee, and retained in the personnel file.

(5) The laboratory shall implement, as a minimum, the following competency and training requirements for each staff member assigned to conduct the test methods for which the laboratory seeks accreditation:

(i) general requirements of the test methods;

(ii) testing laboratory system capabilities (electrical, mechanical, and environmental);

(iii) motor specimen preparation and/or mounting techniques;

(iv) connection and operation of the test equipment;

(v) equipment calibration techniques; and

(vi) data collection, calculation, and analysis, as required.

(6) Relevant reference documents, texts, and current scientific and industry periodicals shall be made available to all technical staff to keep their knowledge up to date.

(e) **Accommodation and environment**

The facility should be able to control the ambient air temperature within the temperature range of 10 °C to 40 °C. Drafts and air currents should be minimized in order to achieve required stable temperature rises during testing. There should be sufficient open space around the motor during testing so as not to restrict the normal air flow around or through the motor during testing. The method for securing the motor to restrict movement during testing should not interfere with the cooling of the motor.

(f) **Equipment and reference materials**

(1) The equipment used for conducting the tests in the EEM program shall be maintained and calibrated (or verified) in accordance with the manufacturer's recommendation, as specified in the test method, or as specified below, whichever results in shorter time periods between calibrations:

Apparatus/Instrumentation	*Frequency*
ammeters, voltmeters, and wattmeters	annually
current transformers (CTs)	every 2 years
potential transformers (PTs)	every 2 years
shunts	every 2 years
data acquisition systems	annually
electronic transducers	annually
frequency meters	annually
resistance measurement equipment	annually
speed sensors	annually
temperature measurement equipment	annually
torque measurement equipment	annually

(2) Provisions shall be available to properly ground the motor and test equipment as may be necessary during testing for purposes of safety.

(3) The power source shall provide phase voltages balanced within $\pm$ 0.5% and the voltages shall be sinusoidal with a voltage waveform deviation factor not exceeding 10%. The average frequency shall be within $\pm$ 0.1% of the specified test value and frequency variation during the tests shall not exceed 0.33% of the average frequency.

(4) Test instrumentation should be properly selected and installed to minimize errors introduced by:

(i) loading of the signal source;

(ii) lead calibration;

(iii) range, condition, and calibration of the instrument;

(iv) inductive or electrostatic coupling of signal leads to power systems;

(v) common impedance coupling or ground loops;

(vi) inadequate common mode rejection; and

(vii) conducted interference from the power line.

(5) All indicating instrumentation used to measure voltage, current, and power shall have an accuracy of $\pm$ 0.2% of full scale. The range of each instrument chosen shall be as low as practical for the motor being tested such that readings are in the upper region of the scale.

(6) The error of instrumentation transformers shall not be greater than 0.3%.

[**NOTE:** When the instrumentation in paragraphs 5 and 6 are calibrated as a system, the accuracy shall be $\pm$ 0.2% of full scale.]

(7) Instrumentation used to measure speed shall have an accuracy within $\pm$ 1 rpm of the reading.

(8) Properly sized dynamometers shall be used such that the coupling, friction, and windage losses of the dynamometer measured at the rated speed of the motor being tested is not greater than 15% of the rated output of the motor being tested. Instrumentation used to measure the output torque of the motor shall have an accuracy of $\pm$ 0.2% of full scale.

[**NOTE:** The requirements for instrument accuracy given in paragraphs 5 through 8 are somewhat more stringent than those in IEEE 112 (CSA C390), because they are based on accuracies required for measuring the efficiency of energy efficient motors. They were recommended to NVLAP by NEMA and DOE during the development of the EEM program, and are expected to be promulgated by DOE in

enacting the EPACT requirements for motor efficiency.]

(g) Measurement traceability and calibration

(1) The laboratory's calibrations may be performed by properly trained staff using calibrated standards, or through contract(s) with a competent external calibration service. All calibrations and characterizations must be done against reference standards that are traceable to national standards maintained by NIST or by a foreign national standards authority that issues reference or calibration materials. It is the responsibility of the laboratory seeking accreditation to determine that, where appropriate, calibration services use reference standards traceable to NIST or a foreign national standards authority. The use of a NVLAP-accredited calibration laboratory fulfills the foregoing traceability requirement. Certificates are required for calibration performed by outside services.

(2) The reference standards used and the environmental conditions at the time of calibration shall be documented for all calibrations. Calibration records and evidence of the traceability of the reference standards used must be made available for inspection during the on-site visit. If calibration is performed in-house by the laboratory, the standard metrological procedures used and the environmental conditions must be documented.

The records for each calibration performed in-house shall contain sufficient information to permit their repetition. The records shall include the identity of personnel involved in sampling, preparation, calibration or testing.

(3) In addition to the information specified in NIST Handbook 150, Sec. 285.33(f)(4), testing equipment or verification records shall include the following:

(i) notation of all equipment variables requiring verification;

(ii) the range of verification;

(iii) the resolution of the instrument and its allowable error;

(iv) identity of the laboratory individual or external service responsible for calibration; and

(v) source of reference standard and traceability.

(h) Calibration and test methods

(1) Laboratories shall use the test procedure described in IEEE 112 Method B (CSA C390 Method 1).

IEEE 112 Method B (CSA C390 method 1) for efficiency measures motor input-output with segregation of losses and indirect measurement of stray-load loss. In this method, the apparent total loss (input minus output) is segregated into its various components with stray load loss defined as the difference between the apparent total loss and the sum of the conventional losses (stator and rotor I^2R loss, core loss, and friction and windage loss) (see IEEE 112 para. 6.4).

(2) Subtest Procedures

IEEE 112 Method B (CSA C390 Method 1) contains a number of steps or subtest procedures, which taken together, constitute the complete test method generating the data upon which motor efficiency is calculated. Because the EEM Program, by definition, accredits laboratories testing the efficiency of electric motors, laboratories seeking accreditation must show competency to conduct all the subtest procedures. NVLAP will not grant partial accreditation to a laboratory demonstrating competency for some, but not all, of the subtest procedures.

It is not necessary that the subtest procedures which make up the complete test sequence determining efficiency be performed in time succession with each immediately following the previous one. The subtests can be performed individually when the operating temperature of the motor is established close to its normal rated load operating temperature prior to obtaining the test data. The individual tests can be characterized as follows:

(i) If a heat run is to be performed, it is to be performed first in the test sequence. The heat run shall be at rated voltage, rated frequency, and rated load

(1.0 service factor). The procedure for performing the heat run is given in detail in IEEE-112 (CSA C390).

(ii) For the subtest under load, (commonly referred to as a load performance test), the temperature of the stator winding shall be within 10 °C of the hottest temperature reading for the rated full load operating temperature prior to beginning the test. The test should be performed as quickly as possible to minimize temperature changes in the motor during the test. The procedure for performing the test is given in detail in IEEE-112 (CSA C390).

(iii) The bearing loss stabilization subtest procedure is to be performed as per IEEE-112 (CSA C390). This test may not be necessary if a heat run was performed.

(iv) The no-load subtest procedure is to be performed as per IEEE-112 (CSA C390). The no-load input power at rated voltage and frequency must be checked for stability. This is accomplished by observing that it does not change by more than 3% between two successive readings over a half-hour time interval prior to performing the test.

(3) Departures from the standardized procedures of IEEE 112 Method B (CSA C390 method 1) are permissible only for conditions based upon technical reasons and must be acceptable to the client. Departures from the procedures must be identified in detail in test reports. Data must be available to show that departures are equivalent to or improve the accuracy and/or precision of the measurement without compromising a given test. On-site assessors may recommend acceptance of the departures to NVLAP but are not authorized to grant approval to the laboratories.

(j) Records

(1) Records may be kept in hard copy or computer form (with an adequate back-up system) and shall be readily accessible and secure. Entries in laboratory notebooks shall be dated and signed or initialed.

Computer-based records must contain entries of pertinent staff/date information for data as required in the quality manual and means to preserve integrity for maintenance of records, without later modifications, as an established safeguard. Records will be reviewed during the on-site assessment by selected sampling.

(2) The records to be maintained include:

(i) acceptance/rejection of motors submitted for test;

(ii) comprehensive logs for tracking samples and test activities;

(iii) original data collected by laboratory;

(iv) calibration and verification data;

(v) data and results of quality control;

(vi) equipment and maintenance records; and

(vii) test reports.

(3) Test records, sufficient to reconstruct test reports, shall be kept for a period of 3 years following the completion of testing, unless a longer period is required by the client, regulation, or the laboratories own procedures.

(k) Certificates and reports

(1) All test reports must contain sufficient information for the conditions to be reproduced at a later time if a retest is necessary. Reports intended for use only by the vendor may conform to vendor/laboratory contract obligations, but must be in accord with NVLAP requirements. Appendix G gives an example of a report form that contains the minimum technical information to be reported by a laboratory for the EEM program.

(2) In reporting the results of the motor tests, efficiency is calculated from the raw data using procedures described in Method B of IEEE 112 and Method 1 of CSA C390. The two calculation procedures differ slightly. For adjusting stator and rotor losses to a specified temperature, Method B of IEEE 112 uses the ratio of the end-of-heat-run temperature rise by

resistance (plus 25 °C standard ambient) to the measured stator temperature at the given load point. In contrast, Method 1 of CSA C390 uses the ratio of the end-of-heat-run measured stator temperature (corrected to 25 °C) to the measured stator temperature at the given load point. If the rise-by-resistance and measured rise temperatures match well, the two standards provide the same calculated efficiencies. If these temperatures are not comparable, the calculated efficiencies will have some variation.

For uniformity in reporting motor efficiency to regulatory agencies (e.g., DOE who administers EPACT, and CSA who administers Canadian regulatory requirements), laboratories accredited in the EEM program must use the calculation procedure given in Method 1 of CSA C390. This requirement is imposed because the EEM program was developed in response to the industry request for a single accreditation program which would comply with the regulatory requirements on energy efficient motors in both the United States and Canada. The NVLAP assessor will examine the calculation procedure during the on-site assessment to determine, among other factors, that the laboratory uses the calculation procedure from Method 1 of CSA C390.

(3) In many cases, raw data collected by computer are collated, reduced, analyzed, or otherwise treated for direct incorporation in the test report. Such treatment involving electronic transmission of the data and writing of the test report is generally performed at the laboratory or at an area close to the facility where the laboratory is located. However, at times, the report may be written at an adjunct facility that is located some distance from the testing laboratory.

In such a case, the laboratory must have in place, with appropriate written descriptions in the quality manual, procedures and documentation for assuring the quality and validity of the data transmission, and their incorporation in the test report.

If organizations use several departments for the discrete functions of testing, data collection, data processing, and test report preparation, it is necessary that lines of responsibility with distinct supervisory positions be defined and that no conflicts exist. The assessor will review the procedures and documentation during the on-site assessment, and also assure that all NVLAP procedures regarding the writing and storage of reports are followed.

Special situations may exist where the facilities for test data generation and test report preparation are not both at the same locale. Under these circumstances, the technical assessor cannot meet those responsible for data analysis and the report preparation at the time of the laboratory inspection. Depending upon the on-site laboratory evaluations of the written descriptions and other documentation for assuring the validity of the data transmission and subsequent report writing, an inspection visit to the adjunct facility may be required. When warranted, the assessor will visit the adjunct facility at additional cost to the laboratory before accreditation is granted or renewed.

When a test report is written at an adjunct facility removed from the laboratory, the report must include the names and addresses of both those responsible for conducting the laboratory tests and for writing the test report. Copies of typical reports written at an adjunct facility must be available at the laboratory at the time of the on-site inspection for review by the inspector for compliance with NVLAP procedures.

(m) Outside support services and supplies

The laboratory must verify or test incoming materials and supplies that affect the quality and accuracy of the test results. Examples include equipment vendors, general laboratory equipment, data processing and acquisition equipment, thermocouples, and thermocouple wire.

APPENDIX A

SAMPLE ACCREDITATION DOCUMENTS

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

ISO/IEC GUIDE 25:1990
ISO/IEC GUIDE 58:1993
ISO 9002:1994

Certificate of Accreditation

DEPARTMENT OF COMMERCE ★ UNITED STATES OF AMERICA ★

LABORATORY, INC.
ANYTOWN, USA

is recognized under the National Voluntary Laboratory Accreditation Program for satisfactory compliance with criteria established in Title 15, Part 285 Code of Federal Regulations. These criteria encompass the requirements of ISO/IEC Guide 25 and the relevant requirements of ISO 9002 (ANSI/ASQC Q92-1987) as suppliers of calibration or test results. Accreditation is awarded for specific services, listed on the Scope of Accreditation for:

EFFICIENCY OF ELECTRIC MOTORS

January 1, 19xx
Effective until

For the National Institute of Standards and Technology

NVLAP LAB CODE: 0000

National Institute of Standards and Technology

NVLAP®

National Voluntary Laboratory Accreditation Program

ISO/IEC GUIDE 25:1990
ISO/IEC GUIDE 58:1993
ISO 9002:1994

Scope of Accreditation

EFFICIENCY OF ELECTRIC MOTORS **NVLAP LAB CODE 0000**

LABORATORY, INC.
1 Main Street
Anytown, USA 00000
John Doe Phone: 301-555-1212

NVLAP Code	*Designation*	*Short Title*
24/M01	IEEE 112	Electric Motor Efficiency—Input-Output with Loss Segregation

for purposes of accreditation, equivalent to:

CSA C390
Method 1

This scope of accreditation covers motors rated from 1 to 200 horsepower.

January 1, 19xx

Effective until

For the National Institute of Standards and Technology

APPENDIX B

GENERAL OPERATIONS CHECKLIST

GENERAL OPERATIONS CHECKLIST

Instructions to the Assessor: This checklist addresses general accreditation criteria prescribed in applicable sections of NIST Handbook 150, *NVLAP Procedures and General Requirements*.

This checklist follows and is numbered to correspond to the *NVLAP Procedures and General Requirements*, Subsection 285.33. The numbers in square brackets identify related checklist items. A small black triangle appears in the left-hand margin of selected lines of text throughout this checklist; the marked text applies only to the Calibration Laboratory Accreditation Program (LAP).

Place an "X" beside each checklist item which represents a deficiency. Place a "C" beside each item on which you are commenting for other reasons. Record the item number and your written deficiency explanations and/or comments in this list or on the attached comment sheets. Place a check beside all other items you observed or verified at the laboratory.

SEC. 285.33 CRITERIA FOR ACCREDITATION

(b) ***Organization and management***

(1) The laboratory shall be:

_____ (i) legally identifiable;

Legal name of laboratory ownership: _____

(ii) organized and shall operate in such a way that its permanent, temporary and mobile facilities meet the NVLAP requirements [see also (b)(2)(i), (c)(2)(ii)];

_____ (iii) properly identified on the NVLAP Application.

(2) The laboratory shall:

_____ (i) have managerial staff with the authority and resources needed to discharge their duties [see also (b)(1)(ii), (c)(2)(ii)];

_____ (ii) have policies to ensure that its personnel are free from any commercial, financial and other pressures which might adversely affect the quality of their work;

_____ (iii) be organized in such a way that confidence in its independence of judgment and integrity is maintained at all times;

_____ (iv) specify and document the responsibility, authority and interrelation of all personnel who manage, perform or verify work affecting the quality of calibrations and tests;

_____ (v) provide supervision by persons familiar with the calibration or test methods and procedures, the objective of the calibration or test, and the assessment of the results. The ratio of supervisory to non-supervisory personnel shall be such as to ensure adequate supervision;

_____ (vi) have a technical manager (however named) who has overall responsibility for the technical operations;

Name of person: _____

_____ (vii) have a quality manager (however named) who has responsibility for the quality system and its implementation. The quality manager shall have direct access to the highest level of management at which decisions are taken on laboratory policy or resources, and to the technical manager. In some laboratories, the quality manager may also be the technical manager or deputy technical manager;

Name of person: _____

_____ (viii) nominate deputy(ies) in case of absence of the technical or quality manager;

Name(s): _____

_____ (ix) have documented policy and procedures to ensure the protection of clients' confidential information and proprietary rights [see also (c)(2)(xviii)];

_____ (x) where appropriate, participate in interlaboratory comparisons and proficiency testing programs [see also (c)(2)(xiv), (c)(6)(ii), (g)(3)];

_____ (xi) have documented policy and procedures to ensure that its clients are served with impartiality and integrity.

(c) ***Quality system, audit and review***

(1) The laboratory shall:

_____ (i) have an established and maintained quality system appropriate to the type, range and volume of calibration and testing activities it undertakes;

_____ (ii) have the elements of the quality system documented;

_____ (iii) ensure that the quality documentation is available for use by the laboratory personnel;

_____ (iv) define and document its policies and objectives for, and its commitment to, good laboratory practice and quality of calibration or testing services;

_____ (v) have the laboratory management which ensures that these policies and objectives are documented in a quality manual and communicated to, understood, and implemented by all laboratory personnel concerned;

_____ (vi) ensure that the quality manual is maintained current under the responsibility of the quality manager [see also (c)(2)(iv)].

Date of quality manual: _____

Date of latest update: _____

(2) The quality manual, and related quality documentation, shall state the laboratory's policies and operational procedures established in order to meet the NVLAP requirements. The quality manual and related quality documentation shall contain:

_____ (i) a quality policy statement, including objectives and commitments, by top management;

_____ (ii) the organization and management structure of the laboratory, its place in any parent organization and relevant organizational charts;

_____ (iii) the relations between management, technical operations, support services and the quality system;

_____ (iv) procedures for control and maintenance of documentation [see also (c)(1)(vi), (j)(1)];

_____ (v) job descriptions of key staff and reference to the job descriptions of other staff;

_____ (vi) identification of the laboratory's approved signatories (list here or in the comments section): _____

_____

_____ (vii) the laboratory's procedures for achieving traceability of measurements;

_____ (viii) the laboratory's scope of calibrations and/or tests;

_____ (ix) written procedures for ensuring that the laboratory reviews all new work to ensure that it has the appropriate facilities and resources before commencing such work;

_____ (x) reference to the calibration, verification and/or test procedures used;

_____ (xi) procedures for handling calibration and test items;

_____ (xii) reference to the major equipment and reference measurement standards used;

_____ (xiii) reference to procedures for calibration, verification and maintenance of equipment;

_____ (xiv) reference to verification practices including interlaboratory comparisons, proficiency testing programs, use of reference materials and internal quality control schemes [see also (b)(2)(x), (c)(6)(ii), (g)(3)];

(xv) procedures to be followed for feedback and corrective action whenever:

_____ a) testing discrepancies are detected, or

_____ b) departures from documented policies and procedures occur;

_____ (xvi) the laboratory management policies for departures from documented policies and procedures or from standard specifications;

_____ (xvii) procedures for dealing with complaints [see also (n)];

_____ (xviii) procedures for protecting confidentiality and proprietary rights [see also (b)(2)(ix)];

_____ (xix) procedures for audit and review;

_____ (xx) a description of the laboratory's policy regarding the use of the NVLAP logo;

▸ _____ (xxi) a statement of the laboratory's policy for establishing and changing
▸ calibration intervals for equipment it controls; and

_____ (xxii) a statement of the laboratory's policy concerning the technique(s) to be used for determining measurement uncertainty and calibration/verification adequacy.

_____ (3) The laboratory shall arrange for audits of its activities at appropriate intervals to verify that its operations continue to comply with the requirements of the quality system. Such audits shall be carried out by trained and qualified staff who are, wherever possible, independent of the activity to be audited. Where the audit findings cast doubt on the correctness or validity of the laboratory's calibration or test results, the laboratory shall take immediate corrective action and shall immediately notify, in writing, any client whose work may have been affected.

The audits shall be objective and be conducted internally or on contract. The audits shall include both general criteria (documents, records and policies) and technical compliance (test methods and practices and calibration procedures).

_____ (4) The quality system adopted to satisfy the NVLAP requirements shall be reviewed at least once a year by the management to ensure its continuing suitability and effectiveness and to introduce any necessary changes or improvements.

_____ (5) All audit and review findings and any corrective actions that arise from them shall be documented. The person responsible for quality shall ensure that these actions are discharged within the agreed timescale.

(6) In addition to periodic audits the laboratory shall ensure the quality of results provided to clients by implementing checks. These checks shall be reviewed and shall include, as appropriate, but not be limited to:

_____ (i) internal quality control plans, such as control charts and other available statistical techniques;

NOTE: Measurement assurance techniques are acceptable means to control the measurement process and consistently produce the highest quality measurements.

_____ (ii) participation in proficiency testing or other interlaboratory comparisons [see also (b)(2)(x), (c)(2)(xiv), (g)(3)];

_____ (iii) regular use of certified reference materials and/or in-house quality control using secondary reference materials;

_____ (iv) replicate testings using the same or different methods;

_____ (v) retesting of retained items;

_____ (vi) correlation of results for different characteristics of an item.

(d) ***Personnel*** [see also (c)(2)(v)]

_____ (1) The testing laboratory shall have sufficient personnel, having the necessary education, training, technical knowledge and experience for their assigned functions.

_____ (2) The testing laboratory shall ensure that the training of its personnel is kept up-to-date.

_____ (3) Records on the relevant qualifications, training, skills and experience of the technical personnel shall be maintained by the laboratory.

(e) ***Accommodation (facilities) and environment*** [see also (i)(3)]

_____ (1) Laboratory accommodation, calibration and test areas, energy sources, lighting, heating and ventilation shall be such as to facilitate proper performance of calibrations or tests.

NOTE: Laboratory design will be, to the maximum extent practical, in accordance with the guidelines found in the NCSL Recommended Practice #7, *Laboratory Design*, July 25, 1993.

_____ (2) The environment in which these activities are undertaken shall not invalidate the results or adversely affect the required accuracy of measurement. Particular care shall be taken when such activities are undertaken at sites other than the permanent laboratory premises.

NOTE: It is expected that environments which do not meet generally accepted norms, such as those found in NCSL Recommended Practice #7, yet which exhibit the stability required to apply necessary correction factors, will be specified by the laboratory for the purpose of assessment of compliance with its own procedures to achieve its stated uncertainties.

_____ (3) The laboratory shall provide facilities for the effective monitoring, control and recording of environmental conditions as appropriate. Due attention shall be paid, for example, to biological sterility, dust, electromagnetic interference, humidity, voltage, temperature, and sound and vibration levels, as appropriate to the calibrations or tests concerned.

_____ (4) There shall be effective separation between neighboring areas when the activities therein are incompatible.

_____ (5) Access to and use of all areas affecting the quality of these activities shall be defined and controlled.

_____ (6) Adequate measures shall be taken to ensure good housekeeping in the laboratory.

NOTE: While it is the laboratory's responsibility to comply with relevant health and safety requirements, this is outside the scope of this assessment.

(f) ***Equipment and reference materials***

(1) The laboratory shall:

_____ (i) be furnished with all items of equipment (including hardware, software, and reference materials) required for the correct performance of calibrations and tests;

_____ (ii) in those cases where the laboratory needs to use equipment outside its permanent control, including rented, leased and client-owned equipment, ensure that the relevant NVLAP requirements are met.

_____ (2) All equipment shall be properly maintained. Maintenance procedures shall be documented. Any item of the equipment which has been subjected to overloading or mishandling, or which gives suspect results, or has been shown by verification or otherwise to be defective, shall be taken out of service, clearly identified and wherever possible stored at a specified place until it has been repaired and shown by calibration, verification or test to perform satisfactorily. The laboratory shall examine the effect of this defect on previous calibrations or tests.

_____ (3) Each item of equipment including reference materials shall, when appropriate, be labelled, marked or otherwise identified to indicate its calibration status.

_____ (4) Records shall be maintained of each item of equipment and all reference materials significant to the calibrations or tests performed. The records shall include:

_____ (i) the name of the item of equipment, software or reference material;

_____ (ii) the manufacturer's name, type identification, and serial number or other unique identification;

_____ (iii) date received and date placed in service;

NOTE: For initial accreditation, the date received and the date placed in service are not considered mandatory requirements for inclusion in laboratory records, although this is encouraged as good laboratory practice.

_____ (iv) current location, where appropriate;

_____ (v) condition when received (e.g., new, used, reconditioned);

_____ (vi) copy of the manufacturer's instructions, where available;

_____ (vii) dates and results of calibrations and/or verifications and date of next calibration and/or verification;

_____ (viii) details of maintenance carried out to date and planned for the future;

_____ (ix) history of any damage, malfunction, modification or repair;

▸ _____ (x) measured value observed for each parameter found to be out of tolerance
▸ during calibration/verification.

(g) ***Measurement traceability and calibration***

_____ (1) All measuring and testing equipment having an effect on the accuracy or validity of calibrations or tests shall be calibrated and/or verified before being put into service. The laboratory shall have an established program for the calibration and verification of its measuring and test equipment. The program will ensure the recall or removal from service of any standard or equipment which has exceeded its calibration interval or is otherwise judged to be unreliable.

_____ (2) The overall program of calibration and/or verification and validation of equipment shall be designed and operated so as to ensure that, wherever applicable, measurements made by the laboratory are traceable to national standards of measurement where available. Calibration certificates shall, wherever applicable, indicate the traceability to national standards of measurement and shall provide the measurement results and associated uncertainty of measurement and/or a statement of compliance with an identified metrological specification.

NOTE: Traceability to national standards includes traceability to standards maintained or defined at national laboratories in foreign countries where applicable. In these cases, traceability is achieved via international standards. This includes intrinsic standards of measurement where available.

Where applicable, the methodology of the *Guide to the expression of uncertainty in measurement*: 1993, shall be used as the basis for expression of uncertainty of the measurement. NIST Technical Note 1297; January 1993, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, is a practical application document written around the *Guide to the expression of uncertainty in measurement*. Where detailed procedures are not used to quantify and combine uncertainties (i.e., use of test accuracy ratio concepts), the sources of uncertainty shall be tabulated and demonstrated to be acceptable for the measurement undertaken.

NOTE: A significant number of intrinsic standards, such as the Josephson Array Voltage Standard and the Iodine-Stabilized Helium-Neon Laser Length Standard, have been developed and are now being used by many national standards laboratories and some industrial laboratories. These standards are based on well-characterized laws of physics, fundamental constants of nature, or invariant properties of materials, and make ideal stable, precise, and accurate measurement standards if properly designed, characterized, operated, monitored and maintained. Where intrinsic standards are used, the laboratory should demonstrate by measurement assurance techniques, interlaboratory comparisons, or other suitable means, that its intrinsic standard measurement results are correlated with those of national or international standards.

_____ (3) Where traceability to national standards of measurement is not applicable, the laboratory shall provide satisfactory evidence of correlation of results, for example by participation in a suitable program of interlaboratory comparisons or proficiency testing [see also (b)(2)(x), (c)(2)(xiv), (c)(6)(ii)].

NOTE: Traceability requirements may also be satisfied by:

(i) internationally accepted standards in the field concerned;

(ii) suitable reference materials;

(iii) ratio or reciprocity measurements; or

(iv) mutual consent standards which are clearly specified and mutually agreed upon by all parties concerned.

_____ (4) Reference standards of measurement held by the laboratory shall be used for calibration only and for no other purpose, unless it can be demonstrated that their performance as reference standards has not been invalidated.

_____ (5) Reference standards of measurement shall be calibrated by a body that can provide traceability to a national standard of measurement. There shall be a program of calibration and verification for reference standards.

_____ (6) Where relevant, reference standards and measuring and testing equipment shall be subjected to in-service checks between calibrations and verifications.

_____ (7) Reference materials shall, where possible, be traceable to national or international standards of measurement, or to national or international standard reference materials.

(h) ***Calibration and test methods***

_____ (1) The laboratory shall have documented instructions on the use and operation of all relevant equipment, on the handling and preparation of items and for calibration and/or testing, where the absence of such instructions could jeopardize the calibrations or tests. All instructions, standards, manuals and reference data relevant to the work of the laboratory shall be maintained up-to-date and be readily available to the staff.

_____ (2) The laboratory shall use appropriate methods and procedures for all calibrations and tests and related activities within its responsibility (including sampling, handling, transport and storage, preparation of items, estimation of uncertainty of measurement and analysis of calibration and/or test data). They shall be consistent with the accuracy required, and with any standard specifications relevant to the calibrations or tests concerned.

NOTES:

(i) Calibration procedures shall contain the required range and tolerance or uncertainty of each item or unit parameter being calibrated or verified. In addition, the procedures shall contain the generic description of the measurement standards and equipment needed with the required parameter, range, tolerances or uncertainties, and specifications for performing the measurement of the calibration or verification, and/or representative types (manufacturer, model, option) that are capable of meeting the generic description for the measurement standards. The procedures shall be consistent with the accuracy required, and with any standard specifications relevant to the calibrations/verifications concerned.

(ii) The laboratory shall ensure that the calibration uncertainties are sufficiently small so that the adequacy of the measurement is not affected. Well-defined and documented measurement assurance techniques or uncertainty analyses may be used to verify the adequacy of a measurement process. If such techniques are not used, then the collective uncertainty of the measurement standards shall not exceed 25% of the acceptable tolerance (e.g., manufacturer's specification) for each characteristic of the measuring and test equipment being calibrated or verified.

_____ (3) Where methods are not specified, the laboratory shall, wherever possible, select methods that have been published in international or national standards, those published by reputable technical organizations or in relevant scientific texts or journals.

_____ (4) Where it is necessary to employ methods that have not been established as standard, these shall be subject to agreement with the client, be fully documented and validated, and be available to the client and other recipients of the relevant reports [see also (k)(2)(x)].

_____ (5) Where sampling is carried out as part of the test method, the laboratory shall use documented procedures and appropriate statistical techniques to select samples [see also (k)(2)(ix)].

_____ (6) Calculations and data transfers shall be subject to appropriate checks.

(7) Where computers or automated equipment are used for the capture, processing, manipulation, recording, reporting, storage or retrieval of calibration or test data, the laboratory shall have written procedures which ensure that:

_____ (i) the NVLAP requirements are complied with;

_____ (ii) computer software, computers or automated equipment is documented and adequate for use;

_____ (iii) procedures are established and implemented for protecting the integrity of data; such procedures shall include, but not be limited to, integrity of data entry or capture, data storage, data transmission and data processing;

_____ (iv) computer and automated equipment is maintained to ensure proper functioning and provided with the environmental and operating conditions necessary to maintain the integrity of calibration and test data [see also (f)(1)];

_____ (v) it establishes and implements appropriate procedures for the maintenance of security of data including the prevention of unauthorized access to, and the unauthorized amendment of, computer records.

_____ (8) Documented procedures shall exist for the purchase, reception and storage of consumable materials used for the technical operations of the laboratory [see also (m)(2)].

(i) ***Handling of calibration and test items***

_____ (1) The laboratory shall have a documented system for uniquely identifying the items to be calibrated or tested, to ensure that there can be no confusion regarding the identity of such items at any time [see also (k)(2)(v)].

_____ (2) Upon receipt, the condition of the calibration or test item, including any abnormalities or departures from standard condition as prescribed in the relevant calibration or test method, shall be recorded. Where there is any doubt as to the item's suitability for calibration or test, where the item does not conform to the description provided, or where the calibration or test required is not fully specified, the laboratory shall consult the client for further instruction before proceeding. The laboratory shall establish whether the item has received all necessary preparation, or whether the client requires preparation to be undertaken or arranged by the laboratory.

_____ (3) The laboratory shall have documented procedures and appropriate facilities to avoid deterioration or damage to the calibration or test item, during storage, handling, preparation, and calibration or test; any relevant instructions provided with the item shall be followed. Where items have to be stored or conditioned under specific environmental conditions, these conditions shall be maintained, monitored and recorded where necessary. Where a calibration or test item or portion of an item is to be held secure (for example, for reasons of record, safety or value, or to enable check calibrations or tests to be performed later), the laboratory shall have storage and security arrangements that protect the condition and integrity of the secured items or portions concerned [see also (e)].

_____ (4) The laboratory shall have documented procedures for the receipt, retention or safe disposal of calibration or test items, including all provisions necessary to protect the integrity of the laboratory.

_____ (5) Tamper-resistant seals shall be affixed to operator-accessible controls or adjustments on measurement standards or measuring and test equipment which, if moved, will invalidate the calibration. The laboratory's calibration system shall provide instructions for the use of such seals and for the disposition of equipment with damaged or broken seals.

NOTE: Tamper-resistant seals are sometimes affixed to equipment to prevent unauthorized access to areas where adjustments or critical components are located.

(j) ***Records***

_____ (1) The laboratory shall maintain a record system to suit its particular circumstances and comply with any applicable regulations. It shall retain on record all original observations, calculations and derived data, calibration records and a copy of the calibration certificate, test certificate or test report for an appropriate period. The records for each calibration and test shall contain sufficient information to permit their repetition. The records shall include the identity of personnel involved in sampling, preparation, calibration or testing [see also (c)(2)(iv)].

▸ **EXCEPTION:** The retention of all original observations, calculations, and
▸ derived data in the calibration record system is not a mandatory requirement
▸ for calibration laboratories, although it is encouraged as good laboratory
▸ practice.

_____ (2) All records (including those listed in (f)(4) pertaining to calibration and test equipment), certificates and reports shall be safely stored, held secure and in confidence to the client [see also (b)(2)(ix), (c)(2)(xviii)].

NOTE: The period of retention shall be specified in the quality manual.

Record retention time specified: _____

(k) ***Certificates and reports***

_____ (1) The results of each calibration, test, or series of calibrations or tests carried out by the laboratory shall be reported accurately, clearly, unambiguously and objectively, in accordance with any instructions in the calibration or test methods. The results should normally be reported in a calibration certificate, test report or test certificate and should include all the information necessary for the interpretation of the calibration or test results and all information required by the method used [see also (k)(4)(i)].

▸ **NOTE:** It is recognized that the results of each calibration do not always
▸ result in the production of a calibration certificate or report. Whenever a
▸ certificate or report is produced, the above requirements shall be met.

(2) Each certificate or report shall include at least the following information:

_____ (i) a title, e.g., "Calibration Certificate," "Test Report" or "Test Certificate";

_____ (ii) name and address of laboratory, and location where the calibration or test was carried out if different from the address of the laboratory;

_____ (iii) unique identification of the certificate or report (such as serial number) and of each page, and the total number of pages;

_____ (iv) name and address of client, where appropriate;

_____ (v) description and unambiguous identification of the item calibrated or tested [see also (i)(1)];

_____ (vi) characterization and condition of the calibration or test item;

_____ (vii) date of receipt of calibration or test item and date(s) of performance of calibration or test, where appropriate;

▸ **EXCEPTION:** Although it is encouraged as good laboratory practice, the
▸ requirement for inclusion of the date received is not mandatory for calibration
▸ laboratories.

_____ (viii) identification of the calibration or test method used, or unambiguous description of any non-standard method used;

_____ (ix) reference to sampling procedure, where relevant [see also (h)(5)];

_____ (x) any deviations from, additions to or exclusions from the calibration or test method, and any other information relevant to a specific calibration or test, such as environmental conditions [see also (c)(2)(xv), (h)(4)];

_____ (xi) measurements, examinations and derived results, supported by tables, graphs, sketches and photographs as appropriate, and any failures identified;

_____ (xii) a statement of the estimated uncertainty of the calibration or test result, where relevant;

_____ (xiii) a signature and title, or an equivalent identification of the person(s) accepting responsibility for the content of the certificate or report (however produced), and date of issue [see also (c)(2)(vi)];

_____ (xiv) where relevant, a statement to the effect that the results relate only to the items calibrated or tested;

_____ (xv) a statement that the certificate or report shall not be reproduced except in full, without the written approval of the laboratory;

_____ (xvi) a statement that the report must not be used by the client to claim product endorsement by NVLAP or any agency of the U.S. Government;

_____ (xvii) the signature of an approved signatory for all test and calibration reports endorsed with the NVLAP logo;

▸ _____ (xviii) special limitations of use; and

▸ _____ (xix) traceability statement.

_____ (3) Where the certificate or report contains results of calibrations or tests performed by subcontractors, these results shall be clearly identified [see also (l)].

_____ (4) Particular care and attention shall be paid to the arrangement of the certificate or report, especially with regard to presentation of the calibration or test data and ease of assimilation by the reader. The format shall be carefully and specifically designed for each type of calibration or test carried out, but the headings shall be standardized as far as possible [see also (k)(1)].

_____ (5) Material amendments to a calibration certificate, test report or test certificate after issue shall be made only in the form of a further document, or data transfer including the statement "Supplement to Calibration Certificate (or Test Report or Test Certificate), serial number ... (or as otherwise identified)," or equivalent form of wording. Such amendments shall meet all the relevant requirements of item (j).

_____ (6) The laboratory shall notify clients promptly, in writing, of any event such as the identification of defective measuring or test equipment that casts doubt on the validity of results given in any calibration certificate, test report, or test certificate or amendment to a report or certificate.

NOTE: Such notification shall quantify the magnitude of error created in the calibration results. The laboratory shall notify customers promptly, in writing, of any customer's measuring and test equipment found significantly out of tolerance during the calibration/verification process. Measurement data shall be reported so that appropriate action can be taken.

_____ (7) The laboratory shall ensure that, where clients require transmission of calibration or test results by telephone, telex, facsimile or other electronic or electromagnetic means, staff will follow documented procedures that ensure that the NVLAP requirements are met and that confidentiality is preserved.

_____ (8) Whenever a laboratory accredited by NVLAP issues a calibration or test report which contains data covered by the accreditation and also data not covered by the accreditation, it must clearly identify in its records, and in the report to the client, specifically which calibration or test method(s), or portion of a calibration or test method(s), was not covered by the accreditation. The laboratory must also inform the client, before the fact, when calibrations or tests requested are not covered by the accreditation.

NVLAP policy regarding calibration and test reports issued by an accredited laboratory, which reference the laboratory's accredited status, requires that any calibration or test report containing data from calibrations or tests which are not covered by the accreditation include:

_____ (i) a statement at the beginning of the report prominently indicating, "This report contains data which are not covered by the NVLAP accreditation"; and

_____ (ii) a clear indication of which data are not covered by the accreditation.

The laboratory must not misrepresent its accreditation. When a client requires or requests accredited services and any of the requested services are not covered by the accreditation, the client must be so advised.

(l) ***Subcontracting of calibration or testing*** [see also (k)(3)]

_____ (1) Where a laboratory subcontracts any part of the calibration or testing, this work shall be placed with a laboratory complying with these requirements. The laboratory shall ensure and be able to demonstrate that its subcontractor is competent to perform the activities in question and complies with the same criteria of competence as the laboratory in respect of the work being subcontracted. The laboratory shall advise the client in writing of its intention to subcontract any portion of the testing to another party.

_____ (2) The laboratory shall record and retain details of its investigation of the competence and compliance of its subcontractors and maintain a register of all subcontracting.

_____ (3) A NVLAP-accredited laboratory intending to subcontract testing or calibration work that will be performed and reported as meeting NVLAP procedures and criteria must:

_____ (i) have in its quality manual a subcontracting policy compatible with the NVLAP policy, with a description of the procedures for administering and implementing those actions to demonstrate the conformance and consistency of the subcontracted laboratory to perform according to NVLAP procedures;

_____ (ii) place the subcontracted work with a laboratory that maintains accreditation established by NVLAP shown by a current NVLAP Lab Code, or provide and maintain current records that demonstrate that the subcontracted laboratory is competent to perform the test(s) or calibration(s) and that it operates in a manner consistent with and in conformance to NVLAP criteria for accreditation;

_____ (iii) clearly identify in its records, and in the report to the client, exactly which data were obtained by the NVLAP-accredited laboratory and which data were obtained by the subcontractor, NVLAP-accredited or not;

_____ (iv) inform its client, before the fact, that it intends to subcontract for completion of all or a portion of the client's work; and

_____ (v) include at the beginning of the report the name, address, and contact person of the subcontracted laboratory(ies), and one of the following statements, as appropriate:

if NVLAP-accredited

"This report contains data which were produced by a subcontracted laboratory **ACCREDITED (NVLAP LAB CODE)** for the calibration or test methods performed"

if not NVLAP-accredited

"This report contains data which were produced by a subcontracted laboratory **NOT ACCREDITED** for the calibration or test methods performed."

The requirements of this section do not supersede any regulation, law, contract specification, or other related conditions which require NVLAP accreditation.

(m) ***Outside support services and supplies***

_____ (1) Where the laboratory procures outside services and supplies in support of calibrations or tests, the laboratory shall use only those outside support services and supplies that are of adequate quality to sustain confidence in the laboratory's calibrations or tests.

_____ (2) Where no independent assurance of the quality of outside support services or supplies is available, the laboratory shall have procedures to ensure that purchased equipment, materials and services comply with specified requirements. The laboratory should, wherever possible, ensure that purchased equipment and consumable materials are not used until they have been inspected, calibrated or otherwise verified as complying with any standard specifications relevant to the calibrations or tests concerned [see also (h)(8)].

_____ (3) The laboratory shall maintain records of all suppliers from whom it obtains support services or supplies required for calibrations or tests.

(n) ***Complaints*** [see also (c)(2)(xvii)]

_____ (1) The laboratory shall have documented policy and procedures for the resolution of complaints received from clients or other parties about the laboratory's activities. A record shall be maintained of all complaints and of the actions taken by the laboratory.

_____ (2) Where a complaint, or any other circumstance, raises doubt concerning the laboratory's compliance with the laboratory's policies or procedures, or with the NVLAP requirements or otherwise concerning the quality of the laboratory's calibrations or tests, the laboratory shall ensure that those areas of activity and responsibility involved are promptly audited in accordance with item (c)(3).

(o) ***Measuring and test equipment (M & TE)***

NOTE: This section applies to the control of measuring and test equipment (M & TE) used to assure that supplies and services comply with prescribed customer requirements. It is based in large part on the requirements found in government audit standards such as MIL-STD 45662A, and is found in Part II of the ANSI/NCSL Z540-1-1994 (Draft) standard.

(1) General requirements for M & TE

_____ (i) The supplier shall establish and document a system to control the calibration/verification of M & TE.

_____ (ii) M & TE used to determine compliance with customer technical specifications shall be calibrated or verified in accordance with sections 285.33(b) through (n).

_____ (iii) The supplier shall have a program to recall for calibration or verification, or remove from service, M & TE that has exceeded its calibration interval, has broken calibration seals, or is suspected to be malfunctioning because of mishandling, misuse, or unusual results.

_____ (iv) All operations performed by the supplier in compliance with these requirements shall be subject to customer verification at unscheduled intervals.

_____ (v) The supplier shall carry out, or arrange to have carried out, periodic quality auditing of the calibration and verification system in order to ensure its continuing effective implementation and compliance with these requirements.

- Based on the results of the audits and any other relevant factors, such as customer feedback, the supplier shall review and modify the system as necessary.

- Plans and procedures for the audits shall be documented. The conduct of the audit and any subsequent corrective action shall also be documented.

(2) Detailed requirements for M & TE

_____ (i) Calibration system description: The supplier shall provide and maintain a written description of the calibration/verification system covering M & TE and measurement standards. The description shall be sufficient to satisfy each requirement of section 285.33(o) and any deviations shall be submitted with supporting documentation to the customer for approval.

_____ (ii) Adequacy of measurement standards: Measurement standards used by the supplier for calibrating M & TE and other measurement standards shall comply with the requirements of items (f)(1), (g)(1), and (h)(2).

_____ (iii) Environmental conditions: M & TE shall be used in an environment controlled to the extent necessary to ensure valid results. Due consideration shall be given to temperature, humidity, lighting, vibration, dust control, cleanliness, electromagnetic interference and any other factors affecting the results of measurements. Where pertinent, these factors shall be monitored and recorded and, when appropriate, correcting compensations shall be applied to measurement results.

_____ (iv) Intervals of calibration and verification: M & TE requiring calibration shall be calibrated or verified at periodic intervals established and maintained to assure acceptable reliability, where reliability is defined as the probability that M & TE will remain in-tolerance throughout the interval. Intervals shall be established for all M & TE requiring calibration unless the equipment is regularly monitored through the use of check standards in a documented measurement assurance process. Check standards must closely represent the item parameters normally tested in the process and the check standard must be verified periodically. Where intervals are used to ensure reliability, the interval setting system must be systematically applied and shall have stated reliability goals and a method of verifying that the goals are being attained. Intervals may be based on usage or time since last calibration or verification. All exemptions from periodic calibration or verification shall be documented. The recall system may provide for the temporary extension of the calibration due date for limited periods of time under specified conditions that do not unreasonably impair the satisfaction of the customer's requirements.

_____ (v) Calibration procedures: Procedures used to calibrate/verify the supplier's M & TE shall comply with the requirements of items (h)(1) and (h)(2).

_____ (vi) Out-of-tolerance conditions: If any M & TE is found to be significantly out of tolerance during the calibration/verification process, the supplier's system shall provide for notification to the user and to the supplier's quality element, if appropriate, of the out-of-tolerance condition with the associated measurement data so that appropriate action can be taken.

_____ (vii) Adequacy of calibration system: The supplier shall establish and maintain documented procedures to evaluate the adequacy of the calibration system and to ensure compliance with these requirements.

_____ (viii) Calibration sources: M & TE requiring calibration shall be calibrated or verified by laboratories that comply with sections 285.33(b) through (n).

_____ (ix) Records: These requirements shall be supported by records documenting that established schedules and procedures are followed to maintain the adequacy of all M & TE. The records for M & TE requiring calibration shall include an individual record of calibration or verification, or other means of control, providing a description or identification of the item, calibration interval, date calibrated, identification of the calibration source, calibration results (data and/or condition status) and calibration action taken (adjusted, repaired, new value assigned, derated, etc.).

_____ (x) Calibration status: M & TE shall be labeled to indicate calibration or verification status. The label shall identify specific date calibrated (day, month, year, Julian date, or equivalent) and the specific calibration due date or usage equivalent. Items not calibrated to their full capability or which have other limitations of use, shall be labeled or otherwise identified as to the limitations. When it is impractical to apply a label directly to an item, the label may be affixed to the instrument container or some other suitable means may be used to reflect calibration status. Tamper-resistant seals are affixed to operator accessible controls or adjustments which if moved will invalidate the calibration. The quality system shall provide instructions for the disposition of equipment with broken tamper-resistant seals.

_____ (xi) Control of subcontractor calibration: The supplier is responsible for assuring that the subcontractor's calibration system conforms to section 285.33 (l) to the degree necessary to assure compliance with contractual requirements. NVLAP accreditation of the subcontractor's laboratory can serve as the basis for compliance with this requirement.

_____ (xii) Storage and handling: M & TE shall be handled, stored, and transported in a manner which shall not adversely affect the calibration or condition of the equipment.

NVLAP LAB CODE: _____

GENERAL OPERATIONS CHECKLIST - COMMENTS AND DEFICIENCIES

Instructions to the Assessor: Use this sheet to document comments and deficiencies. For each, identify the appropriate item number from the checklist. Identify comments with a "C" and deficiencies with an "X." If additional space is needed, make copies of this page (or use additional blank sheets).

Item No.	*Comments and/or Deficiencies*

GENERAL OPERATIONS CHECKLIST - COMMENTS AND DEFICIENCIES

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Item No.	*Comments and/or Deficiencies*

APPENDIX C

SPECIFIC OPERATIONS CHECKLIST

SPECIFIC OPERATIONS CHECKLIST

EFFICIENCY OF ELECTRIC MOTORS PROGRAM

Instructions to the Assessor: The checklist addresses specific accreditation criteria prescribed in Section 285.33 of the Efficiency of Electric Motors (EEM) Program Handbook. Included also are instructions and comments sheets used for observing actual demonstrations of the performance of selected test methods. These criteria supplement and **do not** supersede the *Criteria for Accreditation*, based on Section 285.33 of the NVLAP Procedures, which are addressed in the NVLAP GENERAL OPERATIONS CHECKLIST.

Place an "X" beside any of the following items which represent a deficiency. Place a "C" beside each item on which you are commenting for other reasons. Record the item number and your deficiency explanation and/or comments on the appropriate comment sheet(s). Place a check beside all other items you observed or verified at the laboratory.

1 QUALITY SYSTEM

_____ 1.1 The quality manual provides detailed procedures, including descriptions of equipment, that the laboratory follows in performing electric motor tests.

_____ 1.2 The quality manual lists the types and sizes of electric motors that the laboratory can test under the scope of the IEEE 112 (CSA C390) standard.

_____ 1.3 The quality manual describes practices for maintenance and calibration of the equipment used in conducting the tests on electric motors.

2 PERSONNEL

The personnel competency program for Efficiency of Electric Motors Program includes the applicable portions of the following, as a minimum:

_____ 2.1 General requirements of the electric motor test methods;

_____ 2.2 Electric motor specimen preparation and/or mounting techniques;

_____ 2.3 Electric motor pre-test temperature procedures;

_____ 2.4 Techniques for measuring ambient thermal conditions; and

Use of equipment for measuring:

_____ 2.5 temperature,

_____ 2.6 resistance,

_____ 2.7 torque,

_____ 2.8 power, and

_____ 2.9 speed (rpm).

3 ENVIRONMENT

_____ 3.1 The ambient temperature is within 10 °C and 40 °C.

_____ 3.2 The ambient temperature is relatively stable during the test.

_____ 3.3 The motor is protected from movement of the air resulting from sources other than the motor or loading devices themselves.

_____ 3.4 If the motor was tested at an altitude ≥ 1000 m (3300 ft), appropriate corrections are made.

4 EQUIPMENT AND REFERENCE MATERIALS

4.1 Power Supply

_____ 4.1.1 The power supply is at rated voltage for the motor being tested.

_____ 4.1.2 The line voltages are balanced within 0.5%.

_____ 4.1.3 The voltage waveform deviation factor is ≤ 10%.

_____ 4.1.4 The average frequency is within ± 0.1% of the specified test value.

_____ 4.1.5 The variation in frequency does not exceed 0.33% of the average frequency.

4.2 Loading Device

_____ 4.2.1 The loading device, such as a dynamometer, is appropriate for the size of the motor.

_____ 4.2.2 The friction and windage losses at the rated speed of the motor under test do not exceed 15% of the rated output of the motor.

_____ 4.2.3 The motor is aligned correctly with the loading device (dynamometer).

4.3 Thermocouples

_____ 4.3.1 If thermocouples are used to monitor temperature, they are installed correctly.

_____ 4.3.2 Multiple thermocouples are cross-checked at ambient temperature for accuracy and agreement.

5 CALIBRATION AND TEST METHODS

5.1 General

Other electric motor tests may be conducted in conjunction with motor efficiency testing.

_____ 5.1.1 The latest version of the IEEE Standard 112 (CSA C390) is available. (Note: laboratories accredited in complying with the provisions of EPACT must also have available the version of IEEE 112 that was in effect at the time of enactment of EPACT or as required by any subsequent amendment.)

_____ 5.1.2 Electric motor specimens are properly stored, prepared, and maintained in the appropriate state before testing.

_____ 5.1.3 Electric motor tests are performed correctly.

_____ 5.1.4 Tests are conducted within the specified operating conditions.

_____ 5.1.5 Electric motors are uniquely identified for correlation with the related test report and records.

_____ 5.1.6 Test data forms are properly completed.

_____ 5.1.7 Test reports are complete and accurate for the electric motor specimens.

_____ 5.1.8 Participant staff for the test maintains a dated log book or record.

_____ 5.1.9 Test equipment and instruments meet the test requirements and calibration conditions. Specific calibration requirements for the EEM program are:

- in accordance with the manufacturer's recommendation;
- the test method; or
- as specified below, whichever results in shorter time periods between calibrations:

Apparatus/Instrumentation	*Calibration or Verification Frequency*
ammeters, voltmeters, and wattmeters	annually
CTs, PTs and shunts	every two years
data acquisition systems	annually
electronic transducers	annually
frequency meters	annually
resistance measurement equipment	annually
speed sensors	annually
temperature measurement equipment	annually
torque measurement equipment	annually

The accuracy of the test equipment is within the following limits:

_____ 5.1.10 instrumentation for measuring voltage, current, and power has an accuracy of ± 0.2% of full scale;

_____ 5.1.11 instrument transformers have an accuracy ± 0.3%;

[**NOTE:** When the instrumentation in lines 5.1.10 and 5.1.11 are calibrated as a system, the accuracy shall be ± 0.2% of full scale.]

_____ 5.1.12 instrumentation used to measure speed has an accuracy within ± 1 rpm of the reading; and

_____ 5.1.13 instrumentation used to measure the output torque of the motor has an accuracy of ± 0.2% of full scale.

5.2 Heat Run

_____ 5.2.1 The initial resistance measurement is taken after the motor is exposed to the ambient temperature for a sufficient time for the windings to reach a stable reference temperature.

_____ 5.2.2 If a heat run is performed, it is performed first in the test sequence.

_____ 5.2.3 The heat run test is performed at rated load, 1.0 service factor.

_____ 5.2.4 If the motor is overloaded at the start of the test to shorten the total test time, the overload is kept under 50%.

_____ 5.2.5 The motor is operated at rated load, voltage, and frequency for a sufficient period of time for the temperatures to stabilize with not more than a 1 °C change in temperature rise between two successive readings taken at ½ hour intervals.

_____ 5.2.6 At the conclusion of the test, the resistance between two phases is measured:

- within 30 seconds of shutdown for motors rated 50 hp or less,
- within 90 seconds of shutdown for motors rated 51 to 200 hp, or
- within 120 seconds of shutdown for motors rated above 200 hp.

If the time limits above are exceeded, the following procedure is followed:

When resistance is measured as a function of time after shutdown, the results are plotted and extrapolated back to the appropriate time delay to determine the resistance at shutdown.

5.3 Load Test

_____ 5.3.1 The load test is performed following a heat run, or it is performed at another time and the motor temperature is adjusted by briefly operating the motor at rated load or some overload condition.

_____ 5.3.2 The temperature of the motor winding is within 10 °C of the hottest thermosensor temperature recorded during the heat run at rated operating conditions on a machine under test or on a duplicate machine.

_____ 5.3.3 The temperature is stable at the start of a test.

_____ 5.3.4 The load readings are taken at four points approximately equally spaced between 25% and up to and including 100% of rated load, and two points suitably chosen above 100% but not exceeding 150% of rated load.

_____ 5.3.5 The motor is loaded in decreasing order from the highest to the lowest load.

_____ 5.3.6 The load is steady during the time that the data at each load are recorded.

_____ 5.3.7 When necessary to perform the dynamometer correction test, it is done properly.

_____ 5.3.8 The dynamometer correction test is performed after the load test is completed and the motor is near normal operating temperature.

5.4 No-Load Test

_____ 5.4.1 The motor is operated at no-load until the power does not vary by more than 3% between two successive readings over a half hour time interval before starting the test.

_____ 5.4.2 The test is begun at the highest voltage level and the voltage reduced in steps from that level to the lowest test value.

_____ 5.4.3 The readings are taken at voltages from approximately 125% of rated voltage down to the point where further voltage reduction increases the current or the motor becomes unstable.

6 REPORTS

_____ 6.1 Test reports contain sufficient information for the conditions to be reproduced at a later time if a retest is necessary.

_____ 6.2 Test reports contain the technical information required by the EEM program (see NIST Handbook 150-10, Appendix G, *Report Illustration*).

_____ 6.3 In reporting the results of the motor tests to regulatory agencies, efficiency is calculated from the raw data using the procedure described in Method 1 of CSA C390.

_____ 6.4 The correlation factor for smoothing stray-load loss is 0.90 or higher with no more than one of the six points omitted from the analysis.

_____ 6.5 When necessary to repeat the test to obtain a correlation factor of 0.90 or higher, the source of error is investigated and corrected prior to rerunning the test.

_____ 6.6 The laboratory has in place, with appropriate written descriptions in the quality manual, procedures and documentation for assuring the quality and validity of the electronic data transmission and their incorporation in the test reports.

_____ 6.7 Copies of typical reports written at an adjunct facility removed from the laboratory are available at the laboratory at the time of the on-site inspection for review.

_____ 6.8 When a test report is written at an adjunct facility, the report includes the names and addresses of both those responsible for conducting the laboratory tests and for writing the test report.

EEM SPECIFIC OPERATIONS CHECKLIST - COMMENTS AND DEFICIENCIES

Instructions to the Assessor: Use this sheet to document comments and deficiencies. For each, identify the appropriate item number from the checklist. Identify comments with a "C" and deficiencies with an "X." If additional space is needed, make copies of this page (or use additional blank sheets).

Item No.	*Comments and/or Deficiencies*

APPENDIX D

TEST METHOD SELECTION LIST

NVLAP LAB CODE: _____

EFFICIENCY OF ELECTRIC MOTORS
TEST METHOD SELECTION LIST

Instructions: You are requesting accreditation for test procedure IEEE 112, Method B, which is applicable to tests of electric motors rated from 1 to 250 horsepower. IEEE 112-1991 (Section 6.2.1) indicates that polyphase motors larger than 250 horsepower may be tested by Method B; accreditation for larger horsepowers can be requested. Please indicate on the line below the horsepower range over which your laboratory has the capability to conduct the procedure.

NVLAP Code	*Designation*	*Short Title*
_____ 24/M01	IEEE 112 Method B	Electric Motor Efficiency—Input-Output with Loss Segregation

for purposes of accreditation, equivalent to

CSA C390
Method 1

Accreditation is sought for conducting tests according to IEEE 112, Method B, on electric motors rated:

_____ to _____ horsepower.

Note: Proficiency testing is required for IEEE 112 Method B or for CSA C390. Notification will be given to the laboratory by NVLAP and/or a NVLAP proficiency test contractor.

APPENDIX E

ON-SITE ASSESSMENT - TEST METHOD REVIEW

NVLAP LAB CODE: _____

NATIONAL VOLUNTARY LABORATORY ACCREDITATION PROGRAM

ON-SITE ASSESSMENT - TEST METHOD REVIEW

Instructions to the Assessor:

During the on-site visit you will be required to assess the laboratory's ability to conduct the specific test methods for which it has applied for accreditation. In some cases this will involve many test methods. You may not have sufficient time to perform an in-depth assessment of each method.

Use the attached sheets to indicate which test methods you assessed at the laboratory, and the extent of your assessment. Indicate whether you performed an in-depth review, including a full review of laboratory activities. These include sample control and preparation, procedure review, observation of actual testing, environmental control check, equipment review, calibration checks, record-keeping practices and report forms; or, that you observed selected items to determine that the laboratory demonstrated the ability to conduct the test.

The specific requirements for each test method are detailed in the CRITICAL ELEMENTS, the HANDBOOK, and/or the TEST METHOD. Any items required under "special considerations" will be described either in the CRITICAL ELEMENTS, special instructions below, or in other correspondence.

Fill out the ON-SITE ASSESSMENT - TEST METHOD REVIEW SUMMARY by writing in the test method designation. Indicate on the summary the DEPTH of the assessment for each test method you reviewed, using one of the symbols shown below:

OT - (Observed Test)
EA - (Examined Apparatus)
W/TT - (Walked/Talked Through)
LDP - (Listened to Description of Procedures)

All ***deficiencies*** must be accompanied by a comment.

Use the ON-SITE ASSESSMENT - TEST METHOD REVIEW COMMENTS AND DEFICIENCIES sheets to write comments on what you observed. Preface each comment with the test method designation to which the comment applies. Please be liberal with your comments so that we have a good written record of your observations; the more information we have, the better the accreditation decision we can make.

Special Instruction:

NVLAP LAB CODE:

National Voluntary Laboratory Accreditation Program (NVLAP)

ON-SITE ASSESSMENT - TEST METHOD REVIEW SUMMARY

Test Method (number, name or designation)	Depth of Assessment	Environmental/ Test Sample Conditioning	Test Equipment and Apparatus	Calibration	Test Procedures	Test Reports	Special Considerations

NVLAP LAB CODE: _____

ON-SITE ASSESSMENT - TEST METHOD REVIEW COMMENTS AND DEFICIENCIES

Instructions to the Assessor: Use this sheet to document comments and deficiencies. For each, identify the appropriate item number. Identify comments with a "C" and deficiencies with an "X." If additional space is needed, make copies of this page (or use additional blank sheets).

Item Number	*Comments and/or Deficiencies as Noted on the On-Site Assessment - Test Method Review Summary*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

APPENDIX F

ON-SITE ASSESSMENT REPORT COVER SHEET

NVLAP LAB CODE: _____

National Institute of Standards and Technology
National Voluntary Laboratory Accreditation Program
(NVLAP)

ON-SITE ASSESSMENT REPORT

Laboratory Name_____

Program_____ On-Site Assessment Dates_____

Date Report Reviewed
with Laboratory_____ Assessor's Signature_____

Instructions for the Laboratory:

Respond in writing within 30 days of the date of this report, addressing all deficiencies noted by the assessor. All deficiencies must be satisfactorily resolved before accreditation may be granted. **Each deficiency must be referenced, in your response, by item number as it is listed in the Assessment Report checklists.**

The On-Site Assessment Report conveys the opinion of the assessor as a single representative of NVLAP. The final evaluation of your laboratory, for the purpose of recommending approval or denial of accreditation, will be conducted by NIST technical experts who will review this report, the written information submitted by you, and results of any required proficiency testing. You must respond to this report by identifying the actions you have taken to correct the deficiencies identified. Respond in detail so that an accurate evaluation can be completed. Failure to respond may delay an accreditation decision.

Send your response to: Chief, Laboratory Accreditation Program
National Institute of Standards and Technology
Building 411/Room A162
Gaithersburg, MD 20899

Signed Statement:

The assessor has discussed the contents of this report with members of the laboratory management who agree to respond in writing to NIST, regarding resolution or correction of any deficiencies noted, within 30 days of the date of this report.

_____ _____
Signature of Authorized Representative or designee Printed Name

APPENDIX G

REPORT ILLUSTRATION

This appendix provides an example of a report form that contains the minimum technical information to be reported by a laboratory for the EEM program. The NVLAP assessor will examine the laboratory's reports during an on-site assessment to assure that the minimum information is included.

A sample data report form is shown as an example (only).

TYPICAL EFFICIENCY TEST DATA REPORT FORM

Type _____ Design _____ Frame _____ Model No. _____ Serial No. _____
[Hp][kW] _____ Phase _____ Frequency _____hertz Voltage _____volts Synchronous r/min _____
Temperature Rise _____°C Time Rating _____

RESISTANCE MEASUREMENT

Stator Winding (Wdg) Resistance Between Terminals A-B_____ohms, B-C_____ohms, C-A_____ohms @ _____ °C

HEAT RUN TEST

Voltage: A-B_____ volts; B-C_____ volts; C-A_____volts Current _____amperes Power _____watts
Ambient Temp _____°C Torque _____[N · m] or [lb · ft] Speed _____r/min Frequency _____hertz
[Hp][kW] _____ Wdg Temp _____ °C Wdg Resistance _____ohms

LOAD PERFORMANCE TEST							
Load Point		1	2	3	4	5	6
Ambient Temp., in °C							
Stator Winding Temp., in °C							
Frequency, in hertz							
(Speed)(Slip), in r/min							
Line-to-Line Voltage, in volts:	A-B						
	B-C						
	C-A						
Line Current, in amperes:	A-B						
	B-C						
	C-A						
Stator Power, in watts							
Torque, in [N · m], [lb · ft]							

r/min = revolutions per minute; select bracketed [] units; N · m = newton meter (to convert to lb · ft, divide by 1.355818)

TORQUE CORRECTION TEST

MOTOR-DYNAMOMETER NO-LOAD (FRICTION & WINDAGE)

Voltage: A-B_____volts; B-C_____volts; C-A_____volts Torque _____[N · m][lb · ft]
Current: A-B_____amperes; B-C_____amperes; C-A_____amperes [Hp][kW]_____
Power _____watts Speed _____r/min Frequency _____hertz Wdg Temp _____°C
Ambient Temp _____°C Wdg Resistance _____ohms

MOTOR NO-LOAD

Voltage: A-B_____volts; B-C_____volts; C-A_____volts Power _____watts
Current: A-B_____amperes; B-C_____amperes; C-A_____amperes Speed _____r/min
Frequency _____hertz Wdg Temp _____°C Ambient Temp _____°C Wdg Resistance _____ohms

NO-LOAD TEST

Ambient Temp., in °C							
Stator Winding Temp., in °C							
Line-to-Line Voltage, in volts: A-B							
B-C							
C-A							
Line Current, in amperes: A-B							
B-C							
C-A							
Stator Power, in watts							

TYPICAL EFFICIENCY TEST REPORT CALCULATION FORM

Type _____ Design _____ Frame _____ Model No. _____ Serial No. _____
[Hp][kW] _____ Phase _____ Frequency _____hertz Voltage _____volts Current _____amperes
Synchronous r/min _____ Temperature Rise _____°C Time Rating _____

Average Stator Winding Resistance Between Terminals _____ ohms @ _____°C							
Specified Temperature for Resistance Correction(t_s)= _____ °C (100% Load heat run)							
Item	Description	1	2	3	4	5	6
1	Ambient Temperature, in °C						
2	(t_t)Stator Winding Temperature, in °C						
3	Frequency, in hertz						
4	Synchronous speed, in r/min						
5	Slip, in r/min						
6	Speed, in r/min						
7	Line-to-Line Voltage, in volts: A-B						
	B-C						
	C-A						
8	Line Current, in amperes: A-B						
	B-C						
	C-A						
9	Stator Power, in watts						
10	Core Loss, in watts						
11	Stator I^2R Loss, in watts, at (t_t) °C						

12	Power Across Air Gap, in watts						
13	Rotor I^2R Loss, in watts						
14	Friction and Windage Loss, in watts						
15	Total Conventional Loss, in watts						
16	Torque, in [lb · ft][N · m]						
17	Dynamometer Correction, in [lb · ft][N · m]						
18	Corrected Torque, in [N · m][lb · ft]						
19	Shaft Power, in watts						
20	Apparent Total Loss, in watts						
21	Stray-Load Loss, in watts						
	Intercept _____ Slope _____ Regression Factor _____ Point Deleted _____						
22	Stator I^2R Loss, in watts at (t_s) °C						
23	Corrected Power Across Air Gap, in watts						
24	Corrected Slip at (t_s) °C, in r/min						
25	Corrected Speed, in r/min						
26	Rotor I^2R Loss, in watts at (t_s) °C						
27	Corrected Stray-Load Loss, in watts						
28	Corrected Total Loss, in watts						
29	Corrected Shaft Power, in watts						
30	Shaft Power, in watts						
31	Efficiency, in %						
32	Power Factor, in %						

SUMMARY OF CHARACTERISTICS

Value at indicated percent of rating determined from plot of test results						
Load, in percent of rated	25	50	75	100	125	150
Power Factor, in %						
Efficiency in %						
Speed, in r/min						
Line Current, in amperes						
Total Loss, in watts						

SAMPLE DATA REPORT FORM

TYPICAL EFFICIENCY TEST DATA REPORT FORM

Type _____ Design _____ Frame _____ Model No. _____ Serial No. _____
[Hp][kW] [10][7.46] Phase 3 Frequency 60 hertz Voltage 575 volts Synchronous r/min 1,800
Temperature Rise _____ °C Time Rating _____

RESISTANCE MEASUREMENT

Stator Winding (Wdg) Resistance Between Terminals A-B 1,650 ohms, B-C _____ ohms, C-A _____ ohms @ 18 °C

HEAT RUN TEST

Voltage: A-B _____ volts; B-C _____ volts; C-A _____ volts Current _____ amperes Power _____ watts
Ambient Temp 29 °C Torque _____ [N · m] or [lb · ft] Speed _____ r/min Frequency _____ hertz
[Hp][kW] _____ Wdg Temp 108 °C Wdg Resistance 2.17 ohms

LOAD PERFORMANCE TEST

Load Point		1	2	3	4	5	6
Ambient Temp., in °C		20	20	20	20	20	20
Stator Winding Temp., in °C		37	45	48	48.5	49	49
Frequency, in hertz		60	60	60	60	60	60
(Speed)(Slip), in r/min		1755	1757	1763	1772	1782	1790
Line-to-Line Voltage, in volts:	A-B	575	575	575	575	575	575
	B-C						
	C-A						
Line Current, in amperes:	A-B	13.76	12.90	11.61	9.66	8.03	6.81
	B-C						
	C-A						
Stator Power, in watts		10980	10150	8880	6780	4730	2710
Torque, in [N · m], [lb · ft]		50.7	46.7	40.6	30.4	20.2	10.1

r/min = revolutions per minute; select bracketed [] units; N · m = newton meter (to convert to lb · ft, divide by 1.355818)

TORQUE CORRECTION TEST

MOTOR-DYNAMOMETER NO-LOAD (FRICTION & WINDAGE)

Voltage: A-B 575 volts; B-C _____ volts; C-A _____ volts Torque 3.78 [N · m][lb · ft]
Current: A-B 5.4 amperes; B-C _____ amperes; C-A _____ amperes [Hp][kW] _____
Power 1,520 watts Speed 1,795 r/min Frequency 60 hertz Wdg Temp _____ °C
Ambient Temp _____ °C Wdg Resistance 2.17 ohms

MOTOR NO-LOAD

Voltage: A-B 575 volts; B-C _____ volts; C-A _____ volts Power 780 watts
Current: A-B 5.11 amperes; B-C _____ amperes; C-A _____ amperes Speed _____ r/min
Frequency 60 hertz Wdg Temp _____ °C Ambient Temp _____ °C Wdg Resistance 2.12 ohms

NO-LOAD TEST

Ambient Temp., in °C							
Stator Winding Temp., in °C	54	54	54	52	50	49	48
Line-to-Line Voltage, in volts: A-B	603.7	575	517.5	287.5	230	172.5	126
B-C							
C-A							
Line Current, in amperes: A-B	7.35	6.32	4.92	2.38	1.94	1.51	1.193
B-C							
C-A							
Stator Power, in watts	860	720	540	200	156	120	96

TYPICAL EFFICIENCY TEST REPORT CALCULATION FORM

Type _____ Design _____ Frame _____ Model No. _____ Serial No. _____
[Hp][kW] _____ Phase _____ Frequency _____hertz Voltage _____volts Current _____amperes
Synchronous r/min _____ Temperature Rise _____°C Time Rating _____

Average Stator Winding Resistance Between Terminals 1.650 ohms @ 18 °C							
Specified Temperature for Resistance Correction(t_s)= 104 °C (100% Load heat run)							
Item	Description	1	2	3	4	5	6
1	Ambient Temperature, in °C	20	20	20	20	20	20
2	(t_t)Stator Winding Temperature, in °C	37	45	48	48.5	49	49
3	Frequency, in hertz	60	60	60	60	60	60
4	Synchronous speed, in r/min	1800	1800	1800	1800	1800	1800
5	Slip, in r/min	45	43	37	28	18	10
6	Speed, in r/min	1755	1757	1763	1772	1782	1790
7	Line-to-Line Voltage, in volts: A-B	575	575	575	575	575	575
	B-C						
	C-A						
8	Line Current, in amperes: A-B	13.76	12.90	11.61	9.66	8.03	6.81
	B-C						
	C-A						
9	Stator Power, in watts	10980	10150	8880	6780	4730	2710
10	Core Loss, in watts	535	535	535	535	535	535
11	Stator I^2R Loss, in watts, at (t_t) °C	503	457	374	259	179	129

12	Power Across Air Gap, in watts	9942	9158	7971	5986	4016	2046
13	Rotor I^2R Loss, in watts	249	219	164	93.4	40.2	11.4
14	Friction and Windage Loss, in watts	72	72	72	72	72	72
15	Total Conventional Loss, in watts	1359	1283	1145	959.4	826.2	747.4
16	Torque, in [lb · ft][N · m]	50.7	46.7	40.6	30.4	20.2	10.1
17	Dynamometer Correction, in [lb · ft][N · m]						
18	Corrected Torque, in [lb · ft][N · m]	50.8	46.8	40.7	30.5	20.3	10.2
19	Shaft Power, in watts K = 9549	9340	8610	7510	5660	3790	1910
20	Apparent Total Loss, in watts	1640	1540	1370	1120	940	800
21	Stray-Load Loss, in watts	281	257	225	161	114	52.6
	Intercept 66.4 Slope .0879 Regression Factor 0.987 Point Deleted						
22	Stator I^2R Loss, in watts at (t_s) °C	608	534	433	300	207	149
23	Corrected Power Across Air Gap, in watts	9837	9081	7912	5945	3988	2026
24	Corrected Slip at (t_s) °C, in r/min	56.5	52.4	44.6	33.8	21.6	12.0
25	Corrected Speed, in r/min	1744	1748	1755	1766	1778	1788
26	Rotor I^2R Loss, in watts at (t_s) °C	309	264	196	112	47.9	13.5
27	Corrected Stray-Load Loss, in watts	227	193	146	81.8	36.2	9.15
28	Corrected Total Loss, in watts	1751	1598	1382	1101	898	779
29	Corrected Shaft Power, in watts	9229	8552	7498	5679	3832	1931
30	Shaft Power, in watts	12.4	11.5	10.1	7.61	5.14	2.59
31	Efficiency, in %	84.1	84.3	84.4	83.8	81.0	71.3
32	Power Factor, in %	80.1	79.0	76.8	70.5	59.1	40.0

SUMMARY OF CHARACTERISTICS

Value at indicated percent of rating determined from plot of test results						
Load, in percent of rated	25	50	75	100	125	150
Power Factor, in %	39.2	58.3	70.1	76.9	80.4	
Efficiency in %	70.6	80.8	83.7	84.5	84.1	
Speed, in r/min	1788	1778	1766	1755	1744	
Line Current, in amperes	6.77	7.95	9.58	11.53	13.86	
Total Loss, in watts	778	888	1090	1369	1768	

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